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THE DISCRIMINATIVE ABILITY OF THE PAINTED TURTLE

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FOUR FIGURES

INTRODUCTION

In the experiments herein recounted an endeavor has been made to obtain an accurate measure of the ability of turtles of the species *Chrysemys marginata* to discriminate between lines of different width and direction and patterns of different form. The evidence for or against such discrimination has been obtained by establishing in the minds of the turtles associations between certain kinds of lines and patterns and certain pleasant or unpleasant experiences. The reward for successful choice was food; as punishment for failure the electric shock was used.

Experiments by various investigators upon a fairly large number of animals have shown that associations between light and darkness, black and white and intermediate shades may be established in a number of cases. In relatively few instances have such discriminative associations been established for patterns of different form.

To the systematic zoologist no phenomena in nature are more evident than the occurrence of those slight differences in shape and markings which separate species of the same genus and closely related genera. For the comparative psychologist the question must often arise, Are the higher animals capable of visually appreciating these slight differences in form and marking? Are they capable of using them as signs of specific identity? Whether or not such visual discrimination, if it exists, is partly or entirely subordinate to ability to distinguish through the sense of smell, hearing or touch is another question.

If we attempt to analyse the method by which an animal is able visually to recognize familiar objects it may well be supposed that the impressions which it gains are either general or particular. As men recognize familiar forms and faces at a distance without definitely considering or perceiving the finer details of feature and expression, so animals by observing gross outlines and characteristic movements may draw conclusions as to the nature of the forms around them. Such generalized recognition of familiar objects may be considered, in part at least, to have resulted from an educational process. Its acquisition is the result of long association with the objects in question. Throughout this association an appreciation of certain finer distinctive differences, whether consciously or subconsciously manifest, has been a fundamental factor in producing in the animal mind a concrete appreciation of the object's identity in terms of the whole.

With the human mind such processes are of common occurrence. A stranger first met with is afterward recognized by the recollection of some peculiarity which has been impressed upon us. With further acquaintance we forget the peculiarity or it becomes subconscious, while recognition is based on the broader lines of general association. The systematic entomologist, by laborious examination of detailed structure, differentiates between closely related species of insects hitherto unknown to him. But if he specializes upon the group, his recognition of the various familiar species forming it in time becomes almost intuitive,—he knows them "by sight" without consciously analysing their differential markings.

In the realm of animal intelligence it might be difficult to prove directly that such generalized recognition of individuals and objects was the result of a gradual mental development in which discrimination by appreciation of detail gradually led to a more generalized appreciation of difference. It is possible, however, to subject the animal to tests which will indicate in how far it is able to make fine visual discriminations, and if ability in this respect is evident, it may be concluded that such visual powers have played some part at least in bringing to the mind of the adult animal a realization of the nature of its more intimate surroundings. With the results of such an investigation this paper is chiefly concerned.

DESCRIPTION OF APPARATUS

The apparatus used in all tests is similar in nature to the electric-box apparatus of Yerkes[1] though somewhat modified to make it more adaptable to the habits of turtles. It is shown in relief in Fig. I and in ground plan with boxes removed in Fig. II. The large oblong box in which all of the other apparatus is placed (except some of the electrical connections) is of heavy galvanized sheet-iron, 78 cm. long, 38 cm. wide and with sides 16 cm. high. It is divided into three regions: an entrance room at one end, an insulated area at the other, on which the boxes stand, and a runway between. The entrance room can be shut off from the runway by dropping the slide operated by a string which runs behind the screen. The insulation plate upon which the electric and food boxes stand is of beeswax. It stands 4½ cm. above the floor of the large galvanized box. The floor of the runway and entrance room is covered with clean, washed sand, which in the runway is banked up to form a gentle slope leading from the sand covered bottom to the level of the insulation. Water to a depth of 3 cm. covers the bottom of the entrance room and part of the runway. The shallow water and the sandy approach to the boxes are, of course, simply artificial environmental conditions used in an cndeavor to simulate natural conditions.

The long metal electrode extending in front of the boxes is kept in electrical connection with the water by means of the wet sand which surrounds it. The two metal plates embedded in the insulation are connected with the switch which is in turn connected with the rheostat. The other pole of the rheostat is connected with the water. By means of the switch the current may be directed to either one of the insulated electrodes. This switch is located behind the screen which conceals the operator from observation. A small peep-hole through the screen allows the operator to observe fully the actions of the animal without himself being seen or in any way influencing the animal's behavior. Upon each insulated electrode, well toward the back, is fastened a piece of cork behind which meat may be placed. The cork is of such shape that it acts as a blind,

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[1] **Yerkes, R. M., The Dancing Mouse. New York: The Macmillan Company. 1907.**

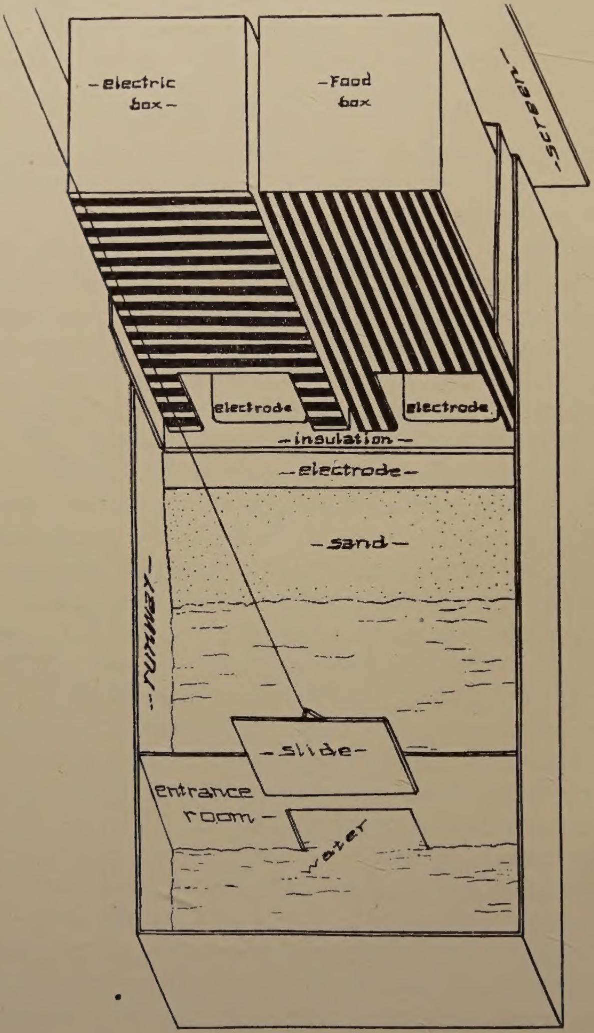

Fig. 1—General view of apparatus.

making it necessary for the turtle to crawl to the back of the electrode before the food is discovered.

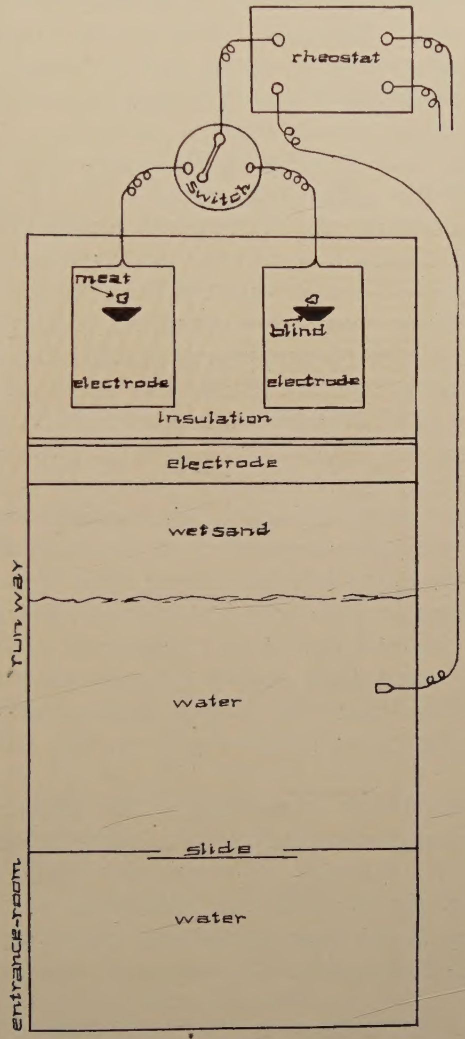

Fig. II—Ground plan of apparatus with boxes removed, showing electrical connections.

The food and electric boxes are of tin, exactly similar in size and shape, their dimensions being, height 26 cm. width 18 cm., depth 17 cm. They are without bottoms, the lower edges of their sides resting upon the insulation plate. The side toward the screen has an opening at the top sufficiently large for introducing the hand in baiting the box. The side toward the runway has an opening at the bottom sufficiently large to allow the turtle to enter easily. The boxes fit loosely in the end of the large oblong box and can readily be removed or interchanged by the operator. They are protected from the sides of the large box by cardboard insulation.

In a few of the earlier experiments the designs or shades used were painted on the boxes, but for several reasons this method proved unsatisfactory and was discontinued. The boxes most generally used are as exactly alike as it was possible to make them. Their distinctive character is given them by the attachment of pieces of cardboard which bear the desired designs. Upon each box are placed two of these boards. One completely covers the outer surface which faces the runway; the other covers the inner surface directly opposite the opening through which the turtle enters in search of food. This latter is immediately behind the cork blind which conceals the food and is intended to give continued emphasis to the design after the outer surface of the box has passed from view. These design boards are fastened to the boxes with small clips and can readily be removed. In practice it was customary to change them from one box to another during or between a set of trials to avoid the chance that the boxes themselves, through some unnoticed peculiarity of form or odor, might aid in influencing the choice.

During most of the experiments the electric current used was taken from a commercial circuit, being reduced to a proper degree by use of a rheostat. The severity of the shock used was varied considerably for different individual turtles. As a rule a shock of very slight degree, one not unpleasantly perceptible to the moistened fingers of the operator, was most effectual.

GENERAL METHODS AND CHARACTERISTIC REACTIONS

All of the turtles upon which observations were made were kept in an aquarium and tamed for from three to six months before experiments were undertaken. This is particularly necessary when dealing with a reptile. *Chrysemys* is probably one of the most tractable water turtles, yet some individuals never become sufficiently docile to allow of satisfactory experimentation. Most of my turtles, however, finally became so tame that they could be handled gently without alarm and would take food readily, even while being held in the hand. A well conditioned *Chrysemys* is a voracious feeder and if not allowed to gorge unduly will be eager for a daily ration of food. It is an active turtle and when well tamed will swim or crawl rapidly to the edge of the aquarium in hope of food whenever anyone approaches. For these reasons it makes a fairly satisfactory experimental animal. Feeding can be used as a reward in the formation of associations and tests can be conducted with a fair degree of rapidity. These statements, however, apply only to turtles which are well tamed and in a satisfactory physiological state. No animal is more unsatisfactory or taxes the patience of the operator more severely than a disgruntled turtle, whether its sulkiness arises from fear or from physical disability.

In describing experiments the term "trial" is used to express one individual attempt to choose between electric and food box. A series of successive trials, usually ten in number and immediately following each other, is denominated a "test." As a rule one test per day was given and upon successive days. In certain cases they were given less often, particularly when a turtle's eagerness for food became lessened. As may be noted from the tables, twenty trials were sometimes given at a test. It was thought that a larger number of trials per day might give better results, but the records show no more than a proportionate acceleration in learning. In all cases an effort was made to subject the animal to tests and trials occurring with a fair degree of regularity.

In practice the turtle to be experimented upon was gently removed from the aquarium and placed in the entrance room. The operator then retired behind the screen having assured himself that the boxes were properly placed and baited and the electrical apparatus adjusted as desired. Food was always placed in both boxes so that its odor, if appreciated, might not serve as a clue. By pulling a string from behind the screen the slide was then raised between the entrance room and the runway and the turtle thus given opportunity to approach the boxes. This might occur immediately or be somewhat delayed according to the inclination of the animal. If the turtle was eager for food it would usually swim rapidly into the runway, crawl up the sandy "bank," making choice the while of the box into which it would enter. If it entered the "right" box it received no repulse but continued on to the back of the box, found the meat hidden behind the cork blind, turned around, scrambled out of the box and down the bank into the water. Here it might stop to eat the meat or might continue on to the entrance room, in which case the slide was immediately dropped and the operator rearranged the boxes. If it remained in the runway while it was eating the meat or afterward, it was urged to enter the entrance room and the slide was dropped before another trial.

If the turtle chose the "wrong" box it received an electric shock at the entrance to the box immediately upon touching the electrode upon the floor of the box with its fore feet or snout, its hind feet being in contact with the long electrode in front of the boxes or with the wet sand. As a rule this caused it to jump backward though it might or might not retire to the water. If the turtle remained in the runway it was, as a rule, replaced in the entrance room and the slide dropped before another trial was given. However, at the beginning of its training, a turtle would at times be allowed to remain in the runway until it found the "right" box and obtained the food from it, though the trial was counted as "wrong" if it at any time approached the electric box sufficiently near to receive an electric shock.

It was considered that a turtle had learned any particular problem when it was able to make a perfect record of correct choices in three successive tests of ten trials each.

The relative position of food and electric boxes was changed with irregular sequence during each series of trials so that learning by an appreciation of regular alternation might be avoided. If no change of position was made between two trials the boxes were lifted and replaced that lack of noise might not give a clue.

Full records were kept during the progress of each experiment showing the relative positions of the boxes at each trial, the time consumed in making each choice, the success or failure of the trial and miscellaneous data regarding the actions of the individual throughout its experimental history. The descriptions of the experiments and the appended tables are summarized from these records.

The above account is a very general one. Many variations occurred in the behavior of turtles during the course of the experiments. Different turtles would differ greatly in the methods by which they seemed to attack the problem, and any individual turtle might vary its course of procedure greatly from time to time. Some of the more accomplished turtles would go through the apparatus with machine-like precision, going straight for a box when the slide was lifted and straight back again into the entrance room after getting their reward or electric shock. But such action was more characteristic of turtles that were nearing perfection in any particular experiment. Such automaticity probably resulted from several rather definite causes. The individual had become, through numerous trials, well accustomed to travel and retravel a beaten path. As a rule its mistakes were few and its mental poise was not continually disturbed by annoying shocks. The most tractable, possibly the most " intelligent " turtles, showed greatest regularity of behavior at this time. Seemingly nervous, erratic turtles, those which appeared never to become entirely tame, showed lack of automaticity. A direct return to the deeper water of the entrance room by a turtle that has succeeded in securing the bait is a natural action, since *Chrysemys* appears unable, or at least unwilling, to tear up and swallow its food unless its mouth is beneath the water.

Unfortunately for the patience of the operator many of the turtles, particularly during the earlier tests of an experiment, were prone to hesitate and wander around in both the entrance room and the runway. Or an individual might leave the entrance room and remain quietly in the runway before the boxes for some time, seemingly deliberating before making a choice. That this was not always mental deliberation upon the particular problem in hand the writer is fairly convinced, for the result of such hesitation was about as likely to be disaster as gain.

Turtles upon receiving the electric shock were diversely affected by it. After a few such experiences some were rendered so nervous and wild that their withdrawal from experimentation was necessary. Others were at first thus affected but gradually became accustomed to the experience or reacted favorably under lessened stimulus. Some were simply rendered sulky and refused to approach the boxes at all or even to leave the entrance room. Some, after each shock, would dart back quickly, turn and scurry away from the box, but were apparently eager to try the experiment again. Others would withdraw slightly from the electrode and would soon after, if allowed, try the same box again or slowly move over to the other box. Any individual might exhibit during the course of an experiment one or several of the idiosyncrasies above noted.

But the most troublesome form of behavior from the standpoint of the operator was the development of a habit of right or left turning. This tendency of an animal always to go either to the right box or to the left, no matter how irregularly their relative positions were changed, might appear at any time during the course of its training. The habit might become firmly fixed or merely be transient; but if not quickly overcome usually put an end to that animal's usefulness for experimental purposes. As a rule such turtles soon became sulky, since they received a large number of shocks.

DESCRIPTION OF TURTLES

The turtles used in all of the experiments were the Western Painted Turtle, *Chrysemys marginata.* This familiar turtle is semi-aquatic in habit, spending much of its time in the water where it may be found crawling over the bottom in search of food, darting through the water in pursuit of more active prey, or floating idly on the surface with head and neck extended. Upon warm days the turtles often leave the water, crawling up the bank or upon protruding logs where they lie basking in the sun. A more extended account of their habits is given by Newman[2].

Except for certain lines and markings *Chrysemys* is not a conspicuous turtle. The carapace is dark olive-green in shade with somewhat lighter markings separating the scutes. The marginal scutes bear dark red and yellow blotches. The plastron is bright yellow. The ground color of the head, neck and legs is similar to that of the carapace, dark olive-green; but the sides of the head and neck are conspicuously striped with bright yellow and red markings, longitudinal in direction, the yellow predominating. The appearance of these conspicuous lines first suggested to the writer the possibility that *Chrysemys marginata* might readily distinguish between differences in line markings since a linear design forms so prominent a feature in the decoration of this species.

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[2] Newman, H. H., The Habits of certain Tortoises, *Jour. Comp. Neur. and Psych.*, 1906, vol. 16, No. 2.

All of the individuals used were collected around Ann Arbor, Michigan, where much of the work was done. Those shipped to Texas did not well undergo the hardships of the journey, nor have they since reacted as satisfactorily as before the trip. For this reason it has been necessary to discontinue the experiments somewhat earlier than had been planned, since their continuance with apparently abnormal animals would vitiate the results of the entire work.

Fifteen turtles were used during the course of the experiments but the records of only seven will be given. For various reasons the results obtained from work on the others do not justify publication. Some sickened and died before the completion of a series of tests; others became sulky, lost appetite, were sluggish or developed permanent habits of right or left turning. The following data refer to those directly mentioned in this paper:

Turtle Number.	Length of Carapace.	Width of Carapace.	Sex.
1	62 mm.	54 mm.	Female.
4	106 mm.	82 mm.	Female.
8	112 mm.	87 mm.	Female.
9	92 mm.	80 mm.	Female.
10	133 mm.	97 mm.	Male.
11	98 mm.	76 mm.	Female.
13	128 mm.	97 mm.	Male.

RESULTS OF EXPERIMENTS

The experiments may be divided into three groups, each group being characterized by the nature of the test to which the animals were subjected. At the beginning of the work the writer desired to obtain some estimate of the ability of *Chrysemys* to form associations. For this purpose the Black and White Discrimination tests were tried, since similar experiments had been conducted by other workers with several other animals. The results of these tests do not bear so particularly upon the problem in hand but are here given for the sake of those who care to make comparisons. The other two groups, those showing the results of tests for Pattern and for Line Discrimination, form the major portion of the work.

BLACK AND WHITE DISCRIMINATION

In these tests the boxes used were painted black and white respectively. Tests with turtles Nos. 1 and 2 were conducted without the use of the electric shock for punishment, food being the only incentive to success and forcible return to the entrance room without reward the only punishment. The apparatus used with these turtles was somewhat different from that already described, being less elaborate and, of course, lacking all electrical connections.

Turtle No. 1 was given, as a rule, ten trials in succession every other day. On several days the turtle was sluggish and a fewer number of trials necessary. In a few instances more than one day intervened, necessitated by the animal's lack of eagerness and activity. It was fed in the white box only. In this experiment no preference tests were taken. The results, given in table 1, show that an association between the white box and food was clearly established. The result of the tests for memory is also to be noted.

Turtle No. 11 was fed in the black box. It was induced to enter this box twelve times before the actual tests were begun. In all other respects it was treated in a manner similar to No. 1. Its record, given in table 2, shows but two perfect tests although the general average of successful trials is good. The two memory tests, taken twelve and twenty-one weeks after the last test of the series, are not perfect though as good as that test.

Turtles Nos. 8, 9, and 13 were tested with black and white boxes during the latter course of the work for the sake of obtaining additional evidence for or against this type of discrimination. Preference tests were made in all cases and the electric shock was used as punishment. Both No. 8 and No. 9 had, in a previous experiment for pattern discrimination, been accustomed to entering black boxes on which white patterns were displayed. Their decided preference for black may thus be explained. In both cases the food box was white so that the former preference had to be overcome. No memory tests were taken. The records of these turtles for black and white are found in tables 3 and 4.

Turtle No. 13 was decidedly the most unsatisfactory animal

TABLE 1

TURTLE NO. 1, BLACK AND WHITE DISCRIMINATION

Fed in white box

TEST.	RIGHT	WRONG
1	8	2
2	2	3
3	10	0
4	2	0
5	7	3
6	10	0
7	9	1
8	9	1
9	8	0
10	9	1
11	8	2
12	9	1
13	8	2
14	10	0
15	10	0
16	8	2
17	10	0
18	10	0
19	9	1
	156	19

Memory test after 6 weeks, 10 right, 0 wrong.

TABLE 2

TURTLE NO. 11, BLACK AND WHITE DISCRIMINATION

Fed in black box

TEST	RIGHT	WRONG
1	9	1
2	8	2
3	8	2
4	9	1
5	9	1
6	8	2
7	9	1
8	7	3
9	9	1
10	8	2
11	7	3
12	9	1
13	10	0
14	10	0
15	8	2
	128	22

Memory tests: After 12 weeks, 8 right, 2 wrong; after 21 weeks, the same.

TABLE 3

TURTLE NO. 8, BLACK AND WHITE DISCRIMINATION

Result of preference trials. Black 34, *white* 16. *Fed in white box*

TEST	RIGHT	WRONG
1	4	6
2	3	7
3	4	6
4	8	2
5	7	3
6	7	3
7	5	5
8	10	0
9	10	0
10	8	2
11	9	1
12	10	0
13	10	0
14	10	0
	105	35

TABLE 4

TURTLE NO. 9, BLACK AND WHITE DISCRIMINATION

Result of preference trials: Black 16, *white* 4. *Fed in white box*

TEST	RIGHT	WRONG
1	3	7
2	2	8
3	3	7
4	4	6
5	8	2
6	6	4
7	8	2
8	5	5
9	7	3
10	9	1
11	10	0
12	10	0
13	8	2
14	8	2
15	10	0
16	10	0
17	10	0
	121	49

TABLE 5

Turtle No. 13, Black and White Discrimination

Result of preference trials: Black 16, *white* 24. *Fed in black box*

Test	Right	Wrong
1	7	3
2	4	6
3	3	7
4	6	4
5	5	5
6	3	7
7	6	4
8	5	5
9	6	4
10	3	7
11	4	6
12	6	4
13	4	6
14	6	4
15	5	5
16	7	3
17	6	4
18	7	3
19	6	4
20	7	3
21	6	4
22	4	6
	116	104

used in any of the experiments described. It was a large, slowly moving, rather sulky animal, extremely difficult to tame and apparently in need of but little food. It early developed a habit of right turning, and at no time during its 220 trials showed consistent improvement. As compared with some others, notably No. 10, it illustrates well the marked difference in behavior which different turtles may show. Its record is given in table 5.

PATTERN DISCRIMINATION

As the sequel will show the above heading should rather read *lack* of pattern discrimination. The patterns used, reduced one-half in size, are shown in Fig. III. Their areas are equal. It may well be argued that the choice of patterns was unfortunate and that designs more markedly different should have been used. The history of but two turtles will be given here. Several others were tried but through seeming lack of ability to profit by their experiences they received so large a number of shocks that they were rendered sulky and work with them had to be discontinued. In several cases, as shown in table 6, the white designs were placed on pendulums and caused to swing slowly back and forth in front of the black boxes in the hope that the moving object would attract and concentrate the attention of the animal. As far as could be observed the results were no more satisfactory. Preference tests were taken in all cases and the electric shock administered for failure. As is shown in tables 6 and 7 only negative results were obtained for discrimination between the two patterns used.

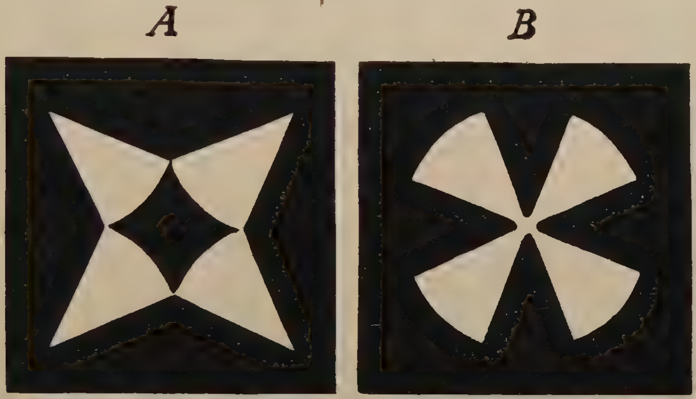

Fig. III—Designs used in experiments on Pattern Discrimination. Reduced one-half

TABLE 6

Turtle No. 8, Pattern Discrimination

Result of preference trials: Pattern A, 19; pattern B, 21. Fed in pattern A box

Test	Right	Wrong
1	4	6
2	2	8
3	7	3
4	5	5
5	0	3
6	6	4
7	1	4
8	5	5
9	6	4
10	4	6
11	5	5
12	6	4
13	3	7
14	6	4
15	7	3
16	3	7
17	6	4
Swinging pattern introduced.		
18	4	6
19	4	6
20	2	8
21	7	3
22	7	3
23	7	3
24	1	9
25	7	3
26	7	3
27	6	4
	128	130

TABLE 7

TURTLE NO. 9, PATTERN DISCRIMINATION

Result of preference trials: Pattern A, 19; pattern B, 31. Fed in pattern A box

TEST	RIGHT	WRONG
1	10	5
2	7	3
3	5	5
4	5	5
5	4	6
6	4	6
7	4	6
8	5	5
9	6	4
10	9	11
11	9	11
12	9	11
13	11	9
	88	87

LINE DISCRIMINATION

The most definite and satisfactory results were obtained in testing for this type of discrimination. The experiments may be divided into two groups:

I. Discrimination between two lined boxes on which parallel lines of equal width run horizontally on one box, vertically on the other.

II. Discrimination between two lined boxes on which the parallel lines run in the same direction on both boxes but are of different width.

In all cases the amount of black and white on the faces of the boxes was the same. Great care was taken that the faces of the boxes exhibiting the lines should show no other difference which might aid the turtle in making a choice. The electric shock was used for punishment and preference tests were taken in all cases.

GROUP I

Experiments in line discrimination under the conditions described for Group I were conducted as follows:

The boxes were faced with cardboards bearing parallel lines, black and white, each 8 mm. in width. On one of the boxes the lines ran vertically, on the other horizontally. Fig. I illustrates the apparatus arranged for this experiment. Preference tests were taken and the box showing the lesser number of entrances was chosen as the food box. Discrimination was then established by a series of tests using difference in the direction of the parallel lines as the criterion of selection. If discrimination was satisfactorily established with the lines 8 mm. in width, the cardboards bearing these lines were then removed and boards bearing lines but 4 mm. wide were substituted on both boxes. If discrimination was fairly maintained after this reduction in the width of the lines they were then further reduced to 2 mm. on both boxes. No lines narrower than 2 mm. were used in the Group I experiments. At each reduction the number of black and white lines on the faces of the boxes was doubled though the amount of black and white surface remained the same. Fig. IV illustrated graphically the various widths of lines used in the Line Discrimination experiments.

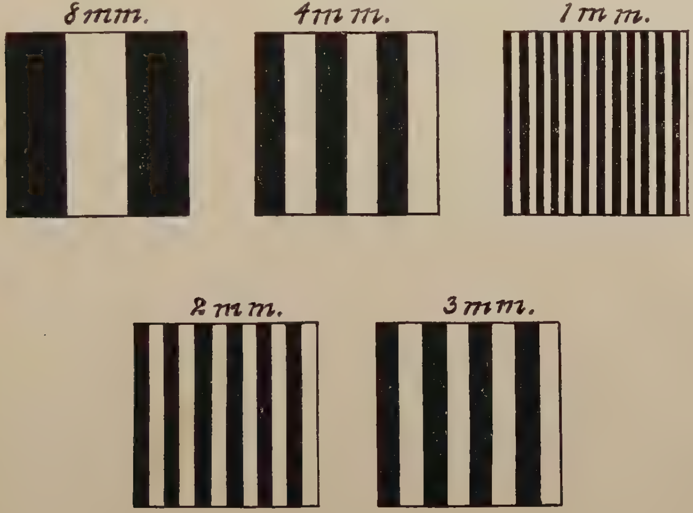

FIG. IV—Graphic representation of the widths of lines used in the experiments on Line Discrimination. The sides of the boxes facing the runway were covered with lines of the widths shown.

The histories of turtles Nos. 4 and 10 illustrate the results of the horizontal-vertical line experiments. No. 10 showed much greater speed in acquiring the association than No. 4. This latter turtle became sulky upon reduction in the width of the lines to 2 mm. No. 10 was in every way my most satisfactory animal. It learned the problem fairly rapidly, showed perfect memory for 8 mm. lines two weeks after learning them, and was able to make distinction with a fair degree of accuracy when the lines were reduced to 2 mm. In the series of six tests (shown in table 8) with lines 4 mm. wide an average of 95 per cent of the trials were correct. When the lines were reduced to a width of 2 mm. on both boxes the first five tests resulted in 80 per cent of the trials being correct. With a continuance of 2 mm. line tests this percentage was lowered in five tests to an average of 68 per cent. It would thus appear that 2 mm. is about the limit of this turtle's discriminative ability for line markings running in different directions. Turtle No. 4 was long in learning the difference between the 8 mm. line boxes. Its first five tests with 4 mm line boxes gave a record of 80 per cent correct choices, and this was raised to 90 per cent in the five succeeding tests. With reduction of lines to 2 mm. the average of successful trials dropped to 54 per cent when the sulky disposition of the animal brought the experiment to an end.

TABLE 8

TURTLE NO. 10, VERTICAL AND HORIZONTAL LINE DISCRIMINATION

Result of preference trials: Vertical 18, horizontal 22. Fed in vertical

Lines 8mm wide

TEST	RIGHT	WRONG
1	5	5
2	2	8
3	4	6
4	4	6
5	10	10
6	11	9
7	15	5
8	16	4
9	18	2
10	9	1
11	10	0
12	10	0
13	20	0
	134	56

Memory test, two weeks

	RIGHT	WRONG
	10	0

Lines 4mm. wide

TEST	RIGHT	WRONG
1	10	0
2	9	1
3	9	1
4	10	0
5	9	1
6	10	0
	57	3

Lines 2mm. wide

TEST	RIGHT	WRONG
1	10	0
2	6	4
3	8	2
4	9	1
5	7	3
	40	10

Lines 2mm. wide (cont.)

TEST	RIGHT	WRONG
1	6	4
2	8	2
3	4	6
4	8	2
5	8	2
	34	16

TABLE 9

Turtle No. 4, Vertical and Horizontal Line Discrimination

Result of preference trials: Vertical 43, *horizontal* 57. *Fed in vertical box*

Lines 8mm wide.

Test	Right	Wrong
1	1	9
2	1	9
3	2	8
4	4	6
5	5	5
6	5	5
7	5	5
8	5	5
9	1	9
10	2	8
11	4	6
12	1	9
13	3	7
14	5	5
15	4	6
16	5	5
17	4	6
18	8	7
19	8	2
20	6	4
21	10	0
22	10	10
23	9	1
24	5	5
25	17	3
26	15	5
27	18	2
28	19	1
29	19	1
30	9	1
31	7	3
32	17	3
33	16	4
34	9	1
35	10	0
36	10	0
37	10	0
	289	166

Lines 4mm. wide

Test	Right	Wrong
1	8	2
2	8	2
3	7	3
4	9	1
5	8	2
	40	10

Lines 4mm. wide (cont.)

Test	Right	Wrong
1	9	1
2	9	1
3	9	1
4	9	1
5	9	1
	45	5

Lines 2mm. wide

Test	Right	Wrong
1	5	5
2	8	2
3	6	4
4	3	7
5	5	5
	27	23

Group II

While the results of the foregoing experiments indicate that turtles can learn to discriminate between two series of lines running in different directions, even though these lines are reduced in width to but 2 mm., they do not necessarily show that the turtles are able to discriminate between individual lines of that width. Since in the previous experiments all of the parallel lines on one box ran vertically and all on the other horizontally, appreciation of difference might simply mean that the turtle discriminated between the general direction taken by the whole series of lines, and would be able to do this until the lines were so reduced in width that only gray surfaces were discerned. The results thus far given are of themselves interesting in that they indicate the ability of these turtles to appreciate the difference between fairly narrow line markings which run in different directions; but they do not serve as an accurate measure of the turtle's ability to distinguish between lines of different width, nor do they give us an exact idea of the extent of the animal's ability to distinguish relative widths of different lines.

So it seemed desirable to conduct another series of experiments in which the lines on the faces and backs of the boxes all ran in the same direction, either vertically or horizontally, but differed in width on the two boxes.

In these tests the turtle was first given choice between two boxes, one of which bore lines 8 mm. wide and the other lines much narrower (1 mm. in one experiment, 2 mm. in the two others described). The records of turtles Nos. 10, 8 and 11 will be presented. Upon both of the boxes used in tests with No. 10 the parallel lines ran vertically; upon those used with Nos. 8 and 11 they ran horizontally. Unfortunately, after establishing discrimination between 8 mm. and 2 mm. lines with turtles No. 8 and No. 11, it was necessary to discontinue the tests. Their records are found in tables 11 and 12.

Turtle No. 10 was carried much farther. It is possible that the former experiences with line boxes which this turtle underwent may, to some extent, have so familiarized it with a similar problem that its performance with these boxes would average better than the rule. No. 10 was started with boxes bearing lines 8 mm. and 1 mm. in width respectively. When this combination was learned the 8 mm. box was refaced with boards bearing lines 4 mm. wide. The choice then lay between a box faced with 1 mm. lines and one faced with 4 mm. lines. The 1 mm. lines had indicated the electric box in the preceding tests and were so retained, while the 4 mm. lines replaced the 8 mm. width on the food box. In fifty trials with these lines 96 per cent of the entrances were correct. The box with 1 mm. lines was then faced with boards bearing 2 mm. lines and a grade of 94 per cent correct was made in fifty trials. In this series the 4 mm. lines still indicated the food box while 2 mm. lines marked the electric box. The 4 mm. lines were next exchanged for a series 3 mm. wide, so that the problem before the turtle was to choose between two boxes bearing lines on their faces which differed but 1 mm. in width. The 3 mm. lines were on the food box, the 2 mm. on the electric box. The first fifty trials of this combination resulted in 82 per cent of the choices being correct and the next fifty trials of the same problem resulted in a grade of 92 per cent correct.

As will be noticed, the changes of line width were alternated

TABLE 10

TURTLE NO. 10, DISCRIMINATION BETWEEN LINES OF DIFFERENT WIDTH

Lines 8, 4 and 3mm. were on the food box. All lines vertical

Lines 8mm. and 1mm. wide

TEST	RIGHT	WRONG
1	2	8
2	3	7
3	6	4
4	9	11
5	9	11
6	12	8
7	16	4
8	18	2
9	10	0
10	9	1
11	8	2
12	9	1
13	10	0
14	10	0
15	10	0
	141	59

Lines 4mm. and 1mm. wide

1	8	2
2	10	0
3	10	0
4	10	0
5	10	0
	48	2

Lines 4mm. and 2mm. wide

TEST	RIGHT	WRONG
1	8	2
2	9	1
3	10	0
4	10	0
5	10	0
	47	3

Lines 3mm and 2mm. wide

1	6	4
2	9	1
3	8	2
4	9	1
5	9	1
	41	9

Lines 3mm. and 2mm. wide

1	10	0
2	9	1
3	10	0
4	9	1
5	8	2
	46	4

from food to electric box so that the turtle always had one box similar to one in a previous series of tests. This arrangement doubtless aided the turtle in maintaining a high average of correct selections. The tests were carried no farther than the 2 mm.-3 mm. combination since it was felt that these lines were sufficiently similar in width to indicate a high degree of discriminative ability. The tabulated results of No. 10's tests are found in table 10.

TABLE 11

TURTLE NO. 8, DISCRIMINATION BETWEEN LINES OF DIFFERENT WIDTH

Lines on both boxes horizontal. 8mm. lines on food box

Lines 8mm. and 2mm. wide

TEST	RIGHT	WRONG
1	5	5
2	7	3
3	6	4
4	3	7
5	8	2
6	6	4
7	7	3
8	7	3
9	8	2
10	14	6
11	6	4
12	9	1
13	5	5
14	8	2
15	7	3
16	9	1
17	9	1
18	10	0
19	10	0
20	10	0
	154	56

TABLE 12

TURTLE NO. 11, DISCRIMINATION BETWEEN LINES OF DIFFERENT WIDTH

All lines horizontal. 2mm. lines on food box

Lines 8mm. and 2mm

TEST	RIGHT	WRONG
1	6	4
2	5	5
3	4	6
4	5	5
5	9	1
6	8	2
7	8	2
8	6	4
9	8	2
10	7	3
11	6	4
12	10	0
13	7	3
14	7	3
15	9	1
16	10	0
17	10	0
18	10	0
	135	45

INCIDENTAL RESULTS

As an aftermath to work on any problem in animal behavior, whether under natural surroundings or experimental control, there may always be gathered certain facts and conclusions not primarily sought in the investigation, yet often bearing important relations to it or yielding interesting data of a more general character. Such results will now be noted.

Individuality. My turtles exhibited distinct individual differences in their mode of behavior under experimental conditions. A few of these have already been noted. Some turtles failed partially or completely to solve problems which others acquired with little seeming difficulty. Such cases of individual failure to learn appear to have been dependent upon two factors: individual lack of mental ability or lack of tractability. It is common knowledge that an animal with a surly disposition cannot be taught tricks. Any turtle that refuses food, retires within its shell upon slight provocation and shows a pronounced disposition to sulk is useless as an experimental animal. Almost any wild adult turtle will act in this manner when first handled but with proper care should gradually become more tractable. However, some of my turtles never became accustomed to captivity and these were finally discarded. Others would respond most satisfactorily for a time and then gradually or suddenly lose interest or become sulky. Such turtles might or might not change in disposition and be useful for later experiments. Without doubt turtles also differ greatly in mental ability. Some appeared willing enough to learn, were cheerful and active, yet did not succeed in learning as rapidly as others.

The persistence of individual characteristic movements. In addition to individual mental characteristics of a general nature some of the turtles showed certain definite peculiarities which were expressed by distinctive movements and reactions. No. 10 almost invariably stopped upon entering the food box and insisted on biting the cork behind which the meat was placed. This was the one persistent "stupid" action of this turtle throughout its experimental history. Occasionally it would simply stop before the cork and crane its neck around the blind until the food came into view. Then it would either advance and proceed to take the food or would bite the cork again before doing so. It seemed continually to labor under the delusion that the reward might most easily be obtained by tearing away the intervening obstruction; at least such an explanation presents itself as a plausible human interpretation of this habit. No other turtle acted in the same way.

Directness or indirectness of approach and entrance into the boxes varied in different cases. As has before been intimated, physical quickness was not necessarily associated with mental alertness or deliberate movements with dullness. Neither was the converse true. The most active turtles were just as likely to choose unwisely as the deliberate ones, and vice versa. But this quality of agility of movement or its reverse usually manifested itself throughout a turtle's performances and was characteristic of the animal. There were a few exceptions to this general rule, cases of sulkiness or sluggishness resulting from ill health or too frequent punishment.

The tendency toward right or left turning was of frequent occurrence during the course of the experiments. Some turtles never acquired it, others for a short time only, but in most cases when it once became established its permanency was assured. The writer has no explanation to offer for the initial cause of such a habit, but merely suggests that once such a tendency is well started its continuance is assured by the potency of kinaesthetic sensation and association. Yerkes[3] long ago showed the facility with which land tortoises learn the windings of a simple maze, and in some early experiments with *Chrysemys* I obtained results which indicate that this water turtle learns such problems with comparative ease. As Watson[4] has shown for the rat, the ability of an animal to learn a maze is largely dependent upon the kinaesthetic sense,—it is a matter of muscular appreciation of distance and direction. Once it is established all other senses are subordinate to it. In the same way it may be supposed that once a tendency toward turning in the direction of a right or left box is (for some unknown reason) established, it will tend to persist even though other senses warn against such procedure.

Mental instability. The mind of the turtle is erratic. A glance over the tables will show instances of pronounced failure closely following successful tests. One day the turtle will be near perfection and upon the next will record a series of failures. Such lapses may occur well toward the end of a series of tests otherwise excellent. I am convinced that these seasons of forgetfulness would continue to occur at irregular intervals no matter how long the training of the animal was continued. With any animal whose mental capabilities are no more highly developed than those of the turtle it is scarcely to be expected that attention to the problem at hand will always be alert or that memory will always serve as a reliable guide.

Influence of former experiences. Much has been written of recent years regarding the influence of past experiences upon animal behavior, and of the necessity of a thorough acquaintance with the past histories of animals subject to experiment. One section of the present work illustrates definitely the effect of such experience upon the animals concerned. This is found in the pronounced preference of turtles Nos. 8 and 9 for black boxes as the result of having participated in a former experiment in which the boxes were painted black to emphasize a white pattern. Had this former experience not been known, and had the turtles in the black-white tests been fed in black boxes without preference tests, the results would probably have given an erroneous idea of these turtles' mental ability. This is, of course, a rather special case, but it serves as a reminder that in dealing with such illusive qualities as mental characteristics the utmost caution must be taken if errors of judgment are to be avoided. On these grounds the results obtained with Nos. 1 and 11 in the black-white tests and also their memory tests are open to question since no preference tests were here taken.

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[3] Yerkes, R. M., The Formation of Habits in the Turtle, *Pop. Sci. Mo.*, 1901, vol. 58, p. 519.

[4] Watson, J. B., Kinaesthetic and Organic Sensations: their rôle in the reactions of the white rat to the maze. *Psych. Rev. Monograph Supp.*, 1907, vol. 8, No. 2.

In discussing No. 10's record for discrimination between lines of different width it was suggested that the relative ease with which it discriminated between lines 2 mm. and 4 mm., and 2 mm. and 3 mm. in width might partly be explained by the fact that immediately before these tests it had passed through a large number of tests of a somewhat similar nature; in other words, that its former experience had to a certain extent prepared its mind to appreciate the latter problem. This is merely a suggestion and no definite claims are made that the animal's mind was more acutely receptive through having previously solved somewhat similar problems. There is far from being sufficient evidence upon which to base statements of this turtle's ability to profit by such educational processes.

The relation of time to successful trials. My work with *Chrysemys* shows conclusively that for this animal any calculation of mental ability based upon the time taken by the turtle on its trips from entrance room to food or electric box can give no accurate measure of its progress in learning. This is particularly true if several individuals are classed together and compared, and it also applies to a comparison of the performances of any one individual if compared at different periods during the progress of an experiment. Not only do different individuals vary greatly in the speed with which they traverse the runway and make choice of the boxes, but any individual's speed may vary enormously, often independently of the failure or success of its choices. It is true that first attempts are usually deliberate and that unsuccessful turtles may be rendered inert through continued punishment, but aside from these considerations the above statement is correct. Without attempting to make too detailed a classification, it may be said that some of the following factors determine the time consumed by a turtle in making its trips from entrance room to box:

(1) temperament of the individual, which would remain fairly constant but would differ greatly if different individuals were compared;

(2) physiological state, varying for the individual during a series of tests and dependent on general health, unavoidable fluctuations in temperature and amount of food taken, though efforts were made to equalize feedings;

(3) temporary mental state, varying for the individual during a series of tests, as sulkiness and inertness caused by an unfavorable physiological state or by undue sensitiveness to punishment.

For the above reasons the time records are deemed of little value and are not given in the published tables though they were taken in all the experiments.

SUMMARY AND CONCLUSIONS

Turtles of the species *Chrysemys marginata* were tested for their ability to discriminate between, (a) black and white; (b) two patterns of different shape; (c) two series of parallel lines of equal width but running in different directions; (d) two series of parallel lines of different width running in the same direction.

Associations were established by the use of food and electric boxes except in two experiments where the electric shock was not used as punishment for failure. The apparatus employed was similar in construction to the electric-box apparatus of Yerkes, though considerably modified for adaptation to the habits of turtles.

Negative results only were obtained in the experiments for pattern discrimination. It is felt that these results are not conclusive, since the patterns used are somewhat alike in general symmetry.

In the black-white tests discrimination was established with four turtles, while one other turtle failed to show improvement in 220 trials.

Two turtles learned to discriminate between two series of parallel lines 8 mm. wide, one vertical and the other horizontal in direction, and showed a fair degree of discrimination when these lines were reduced to 4 mm. in width. One of these turtles did well with a further reduction of the lines to a width of 2 mm. on each box.

Two turtles learned to discriminate between two series of parallel horizontal lines 8 mm. and 2 mm. in width respectively. One turtle learned first to discriminate between two series of parallel vertical lines 8 mm. and 1 mm. wide, next between lines 4 mm. and 1 mm. wide, then between lines 4 mm. and 2 mm. wide, and finally showed an excellent average of discrimination between lines 3 mm. and 2 mm. in width.

Chrysemys does not learn rapidly. An average taken of all the experiments shows that about 183 trials were necessary to establish discrimination. If one experiment is omitted in which 455 trials were given, the average is reduced to 154 trials. In these calculations the three final perfect tests are not counted, neither are tests with reduced lines considered, only those line experiments being taken in which discrimination was first being established.

Two of the memory tests are surprisingly good but are subject to question, no preference tests having been taken. The third, showing perfect memory two weeks after the vertical-horizontal line tests is unquestionably accurate. These results indicate a fair degree of retentiveness.

The amount of evidence at hand does not justify general conclusions regarding the relative intelligence of turtles of different age or different sex.

The turtles studied exhibited marked individual differences in disposition and in mental ability.

More particularly from the results of the line experiments it may be concluded that *Chrysemys* is able to appreciate differences in the direction of line markings even though the lines be narrow, and differences in the width of lines even though these be slight in amount. These results suggest that the discriminative faculty thus shown may have been an important factor in the development of the mind of the growing turtle and that in the common activities of its daily life the individual's behavior may often be determined by its ability to appreciate differences of direction, though but lightly marked, and to distinguish accurately between slight differences of extent.

THE REACTIONS OF MOSQUITOES TO LIGHT IN DIFFERENT PERIODS OF THEIR LIFE HISTORY

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Everyone is familiar with the quick wriggling downward of mosquito larvae upon one's approach. Pass your hand over a jar in which the larvae are hanging from the surface film and they will quickly dart towards the bottom. The movement is not an effort to get away from the source of the shadow. It is not simply a tropism. It is a specific reaction to shadows, or a sudden diminution of light intensity, by swimming downward. Nevertheless there seems to be an element of negative phototaxis in the behavior of the larvae when stimulated by shadows, although otherwise they may show a positive reaction to light. These conclusions are borne out, I think, by the following experiments:

A glass jar containing numerous larvae of *Culex territans* and *C. pipiens* was placed before a window through which the light fell upon the jar obliquely from above. A dark object was passed over the jar; the larvae quickly swam downward and toward the side of the jar away from the light. Numerous repetitions of the experiment gave the same result. When the larvae were brought into a dark room and illuminated from one side a shadow thrown upon them would cause them to go downward and away from the light as before. The direction of the light rays is therefore a factor in causing the direction of the movements of the larvae. I have often noticed that specimens in a jar before a window swam downward and away from the light upon my approach, regardless of the direction in which I came. This led me to ascertain whether the larvae would swim away from an approaching object or would simply swim downward and away from the light when stimulated by a shadow or large object in their visual field. The latter was found to be true. In jars before a window the wrigglers would repeatedly swim directly towards my hand if it was moved toward them on the side away from the light. Specimens taken into the dark room and illuminated from one side by an incandescent electric lamp would react in the same way. A jar of larvae was then placed on a glass plate on a tripod and illuminated from below. When my hand was passed beneath the jar, thus throwing a shadow on the larvae from below, they would swim downward as before. Momentarily turning off the light produced the same effect. An object placed on a fine wire and brought near the wriggler from below when it was hanging from the surface film would invariably cause a sudden descent towards the approaching object. When larvae are on the bottom, shadows thrown upon them either from above or below simply set them into commotion, which does not issue in any very definitely directed movements.

Notwithstanding this peculiar reaction to shadows and the direction of the light rays the larvae of *Culex* often show a markedly positive phototaxis. Frequently I have seen them gathered on the side of their jar toward the window and when brought into a dark room and exposed to an incandescent, sixteen-candle power electric lamp they swim over toward the more illuminated side of the dish. Larvae vary greatly in their phototactic response. Many seem entirely indifferent to the light. Certain individuals swim toward it eagerly and will follow it about when it is passed from one side of the dish to the other, with great promptness. One lot of larvae three days old was strongly positive, the whole troop swimming over to whatever side of the dish the light was held. The same larvae, however, when suddenly struck by a shadow will go away from the light rays with equal readiness. Mosquito larvae are very sensitive to jars. Tapping lightly on their vessel sends them quickly downward. Placed before a window or illuminated from one side by an artificial light they swim downward and away from the light whenever they are jarred just as they do when disturbed by a shadow.

There is no orientation in the light response. This is in fact practically impossible owing to the peculiar method of swimming which consists in bending the body rapidly from one side to the other. The larvae swim sidewise or obliquely to the direction of the rays when they go toward the light, as they do in swimming away from it. When they have arrived at the positive side of the dish the position of the body bears no relation to the direction of the rays of light. The lack of orientation in the larvae may not be of significance in regard to the nature of the phototactic response, as any orienting tendency which may be present and which may perhaps account for the direction of locomotion would naturally be obscured by the contortions of the larvae during their progress through the water. Age makes little difference in the reactions to light. Experiments tried with larvae less than a day after hatching, elicited the same responses as in older larvae although they were a little less decided. The behavior of the pupae, up to even a short time before the emergence of the imago, is practically the same as that of the larvae both as regards reactions to shadows and positive phototaxis. The reactions of the larvae and pupae of *Culiseta inornatus*, *Aedes fuscus* and *Aedes curriei* are essentially the same as in the species of Culex above described.

Larvae exposed frequently to shadows gradually fail to respond to them. A dish containing about thirty three-day old larvae was shaded by passing an object over it once every minute, the object being passed as nearly as possible in the same way and with the same degree of speed. At the first trial all (about twenty-five) which were at the surface went down. At the second shading about fifteen went down, leaving nine at the surface. In subsequent trials the number remaining at the surface gradually decreased. From the twelfth to the sixteenth trials none descended; in the seventeenth, six went down, after which numerous subsequent trials produced no response. In another lot all failed to respond after the seventh trial. Other experiments yielded very similar results. One lot of larvae was rather exceptional, however, in that they rapidly diminished in responsiveness in the first three shadings, but up to the fifty-fifth trial there was no further reduction in the number descending.

The adult mosquitoes, like the larvae and pupae, show a peculiar combination of reactions to light. It is well known that they are much more apt to settle upon dark objects than upon light ones, and that people wearing dark clothes are more apt to attract them than those with light-colored apparel. During the day they seek the shade, even when it is not hot or dry, and darkness brings them out of their haunts. Within doors, while occasionally found on the windows and the light areas of the room, they very frequently retreat into the shaded nooks. But like most moths and many other forms which seek the shade, they frequently show a decided positive phototaxis.

They sometimes fly to lights at night, but some species manifest little tendency to go towards the light under any conditions. *Culiseta inornatus*, *Aedes fuscus* and two species of Culex, *C. pipiens* and *C. territans*, with which I have experimented, show a marked positive phototaxis. They keep on the sides of their cages nearest the window and in the dark room they follow the light in any direction. When collecting them in vials it is only necessary to hold the closed end towards the sun to be able to put in the cork without the insects escaping. This positive phototaxis is shown as strongly the first day after emergence as after specimens have been kept some weeks in confinement. After a full meal, although more sluggish, they are still positive. The males show the same positive reactions as the females.

A STUDY OF TRIAL AND ERROR REACTIONS IN MAMMALS

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THREE FIGURES

I.	Introduction; Description of Apparatus; Description of Method.......	33
II.	Description of Subjects..	39
III.	Tabulation of Preliminary Analysis of Results......................	44
IV.	Determination of the Different Modes of Adjustment Manifested......	48
V.	Interpretation of Results......................................	56
VI.	Summary and Conclusions..	63

I. INTRODUCTION; DESCRIPTION OF APPARATUS; DESCRIPTION OF METHOD

The literature of animal behavior contains considerable experimentally obtained evidence that among the mammalia there are marked differences of ability to profit by experience, but these differences have been analysed almost exclusively in terms of sensory equipment and of quantitative measurements of reaction time and reactive errors. The trial and error mode of adjustment has thus come to serve the student of behavior as a conceptional unit in his analyses of mammalian reactions, and has been dealt with as genetically variable only with reference to the degree of rapidity with which it leads to the formation of associations appropriate to given situations, and to the elimination of useless activities. We speak of qualitatively different instinctive adjustments, but not of qualitatively different "try-try-again" (trial and error) efforts to meet a situation for which there is no specifically appropriate instinct, no opportunity for imitation of any kind, and no rational equipment.

The present investigation seeks to collect facts of behavior which may lend themselves to qualitative interpretations of trial and error activities. In other words, it is concerned with the following problem: *What, if any, are the qualitative differences of reactive tendency that account for the fact that some mammals learn slowly, and with many errors, to meet situations which their fellows of superior age or race learn to meet quickly and with but few errors?*

We cannot know how to attack this problem, nor specifically what to look for, until we gain a general orientation concerning the facts relevant to it. With this in mind I have made use of the apparatus and method described below.

Description of apparatus. The reader will more clearly understand the purpose of the apparatus by picturing to himself a room which may be entered by a door capable of giving entrance only, and which may be gotten out of by means of a constantly varying one of four possible doors of exit. Let us then imagine that from within the room one may see on each of the five doors a distinctive inscription, as follows:

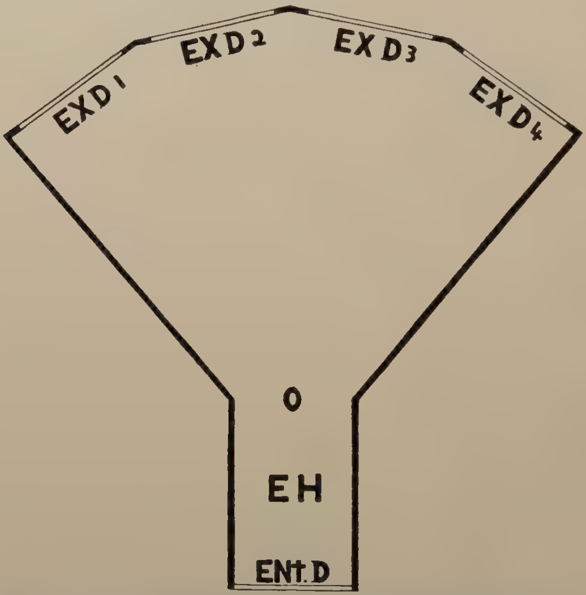

FIGURE 1—Floor plan of apparatus. EntD, Entrance Door; O, point of equidistance from exit doors; ExD 1, ExD 2, ExD 3, ExD 4, Exit Door number 1, Exit Door number 2, etc.

Entrance door: *cannot be used for exit.*
Exit door No. 1: *push against it; will afford exit unless it is locked.*
Exit door No. 2: (*same inscription*).
Exit door No. 3: (*same inscription*).
Exit door No. 4: (*same inscription*).

The apparatus differs from this imaginary room in that its various doors are not labelled at all, and are all alike in appearance, so that a subject seeking exit from the apparatus must gain by experience the information that the above inscriptions would have afforded.

The floor of the apparatus is of wood, and the top of wire netting, and both are of the form shown in Fig. 1. The narrow, rectangular part of this figure represents the *entrance hall* (EH, Fig. 1). This hall can be entered by way of an *entrance door* (Ent. D, Fig. 1), which will swing in the inward direction only, and which fits so snugly within its frame that, once it is closed, it cannot be opened from within the apparatus. It is hung a little out of plumb, so that it will always swing to the closed position when not actually held open by the subject.

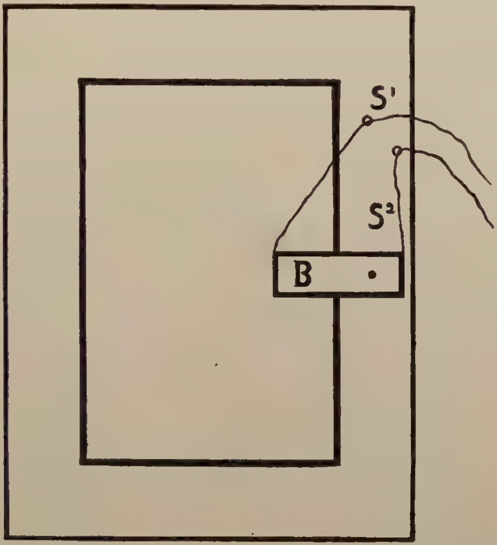

FIGURE 2—An exit door, set within its frame, and equipped with button and button strings. B, Button; S^1, String number 1; S^2, String number 2.

At the opposite, broader end of the apparatus are four *exit doors* (Ex D-1, Ex D-2, Ex D-3, Ex D-4, Fig. 1). Each of these exit doors opens outward only, and when released from pressure swings to the closed position. Like the entrance door, the exit doors are hung out of plumb.

The *exit doors* just described are equidistant from point O in Fig. 1.

Figure 2 is intended to show the manner in which the various exit doors can be "locked" or "unlocked" without the subject's knowledge. It represents the outer aspect of an exit door, set within its frame, and equipped with a *button* (B, Fig. 2) and two *strings* (S-1, S-2, Fig. 2). When the experimenter pulls the string attached to the inner end of the button (S-1, Fig. 2) the latter is brought to the vertical position and the door is thus unlocked. When the string attached to the outer end of the button (S-2, Fig. 2) is pulled, the button assumes the horizontal position, thus locking the door. The subject has nothing to do with the manipulation of these strings, which are carried in metal eyes to the under surface of the apparatus, whence they are carried in grooves, thoroughly concealed, to any part of the laboratory from which the experimenter can operate them without the subject's knowledge. Each of the four exit doors is thus equipped with a button and two strings.

The sides of the apparatus are of wire netting. The inner surfaces of the exit doors are painted greyish-white, whilst the remainder of the interior of the apparatus is dark green. The exit doors have no individually distinctive marks.

The dimensions of the apparatus are determined according to the following general rule: the subject's length being "1," the uniform inside height of the apparatus is "3;" the height of the entrance and exit doors is "2.9" and their width "2." From point O (Fig. 1) to the mid-point of each exit door's lower margin is "6." The various doors are sand-papered to prevent binding.

In order to meet special conditions I have made various unimportant modifications of the apparatus just described. The human subjects, by reason of their upright position in walking, required a relatively higher apparatus. For the horse an apparatus was provided which had "exit doors" merely wide enough to enable him to thrust his head and neck into a food box just beyond; after a trial he was led out of the entrance end of the apparatus. The monkeys so resented handling that their apparatus had to be built within a larger enclosure which, in turn, adjoined their living rooms. In every case the following essential condition was met: the subject, once within the apparatus, was unable to discover whether a given exit door was locked or unlocked except by actually pushing against it.

Description of method. (1) *Preliminary training.* It was found to be desirable to give the animal subjects thorough familiarity with the apparatus before their formal trials were begun, hence, a subject's first experience with the apparatus was merely that of entrance into it, with all the doors propped open and with food scattered about on the floor. After he had eaten he was coaxed out of one of the entrance doors. This was repeated until the subject was thoroughly familiar with the interior of the apparatus as a feeding ground, and with the open exit doors as the most convenient avenues of approach to a desirable locality. In the case of the horse this differed in that the feeding ground was, from the start, a place just beyond any of the exit doors.

The next step in training the subject for the experiment was to close the entrance door as soon as he had entered the apparatus. As soon as this had ceased to produce any evidence of uneasiness the four exit doors were left partially closed, so that the subject was compelled to exert some pressure against any of the exit doors through which he sought to escape. As the training advanced the exit doors were left more and more nearly closed until they were quite closed, although still unlocked. The subject was considered "trained" as soon as he had learned to seek the exit doors for escape from the apparatus, and to push against them without hesitation.

(2) *Formal trials.* The description of these trials, which constitute the experiment proper, will be facilitated by speaking of the various exit doors as if they were numbered "1," "2," "3" and "4," in order, from left to right. For the *first formal trial* of any subject three of the exit doors were locked by the experimenter, who pulled the appropriate button strings without the subject's knowledge. The remaining exit door, *and only that one door* was left unlocked. From within the apparatus, therefore, all four exit doors looked alike, i. e., closed. With the apparatus thus prepared, the subject was placed within it for his first trial, and was allowed to choose his own time for effecting his escape. As soon as he found the one unlocked exit door and effected his escape he was rewarded with food.

For the *second formal trial* the one unlocked door of the first trial was locked, and another of the exit doors was unlocked. Thus, if door 4 were the unlocked door for the first trial, it would be one of the three *locked* doors for the second trial. Each succeeding trial in a total series of 100 trials differed from the trial immediately preceding it according to the same principle: the unlocked exit door of the immediately preceding trial was always one of the three locked exit doors during the present trial.

A second condition of the formal trials was this: during each subject's 100 trials, each exit door was left unlocked for twenty-five trials and locked for seventy-five trials, and care was taken by the experimenter to avoid a discoverable sequence in selecting an ever-varying exit door to be left unlocked. Even the most sophisticated human subject was thus left in ignorance as to which of three inferentially possible doors of exit would open when pressed against until he had actually tried one or more of these doors. Ten consecutive trials were given each subject daily for ten successive days.

The older human subjects were given no preliminary training, but were frankly told that no tricks would be played, and that they were expected to leave the apparatus by way of an exit door. The human infant was given essentially the same training that the animals received, except that in his case toys were substituted for food when my commendation proved insufficient as a motive for reaction.

Before we enter into a discussion of results, two obvious defects of the above method must be taken into account: (1) The situations may have had different sensory values for the different subjects. For example, the dogs of my experiment were unmistakably guided by local odor signs in their discrimination of one exit door from another, whilst these signs were of no value to the human subjects, and probably of but little value to the cats and monkeys. On the other hand, the monkeys may have detected fine differences of visual appearance of the inner surfaces of the exit doors, whereas these doors certainly presented no such differences for the human subjects, and may have been visually indistinguishable to the cats, dogs, and horse.

A fairly satisfactory solution of this difficulty was effected by the preliminary training, which taught the subjects to discriminate among the various exit doors by their differences of spatial position.

(2) There was no adequate measurement of the reactive value of the motives supplied to the various subjects for escaping from the apparatus with the greatest possible speed and accuracy. Yerkes' and Dodson's (1) discoveries concerning the relation

of strength of stimulus to rapidity of habit formation impose on the student of behavior a scientific obligation to regulate as accurately as possible the strength of motive-stimuli. Unfortunately, the easily regulated painful stimuli (electric shock) that proved so useful in their work with the Dancing Mouse cannot be applied where one seeks comparable results from subjects who differ so widely in emotional responsiveness to frequently recurring discomfort as do, for example, dogs and monkeys. Even in the case of my naive human subjects, the possibility that the size of the reward or the degree of my approbation might be affected by stupidity or cleverness of reaction had to be ruled out in order to obtain uniform results.

By observing, for each individual, the relation between strength and kind of motive on the one hand, and uniformity of reaction on the other hand, I was able to secure results which I believe to be quite safely comparable for the purposes of the present exploratory investigation. The animal subjects were never used for experiment until their hunger was partially appeased, and if they chose to lie down and sleep while within the apparatus they were merely urged to return to me for a bit of extra-tempting food. With cats and dogs an atmosphere of lazy comradship with their master greatly favored a steady, apparently unemotional quest of the unlocked door. The horse's natural habit of seeking food over prolonged periods of time rendered him an excellent subject. The monkeys would doubtless have given more uniform results had there been any way of overcoming their natural distractibility, but the food seeking aspect of the experiment proved to be most helpful in reducing the effects of their tendency to shift their attention from the apparatus to fortuitous sights and sounds.

II. DESCRIPTION OF SUBJECTS

The selection of subjects for experiment was made with reference to the desirability of covering considerable ontogenetic and phylogenetic ranges without thereby impairing the value of the results for comparison. Since it was more relevant to the purpose of the investigation to explore for different kinds of adjustment than to make an intensive study of any particular mode of adjustment, no effort was made to obtain averages for large numbers of individuals belonging to a given age or species.

The many gaps in the age and phyletic series are due to the fact that the results obtained from many of my subjects had to be rejected for various reasons. Some of the subjects were stolen and some died before their trials were completed; in some cases I could not be reasonably sure that a possible difficulty in discriminating one exit door from another did not exist; and many unavoidable interruptions rendered it impossible to make use of all the subjects that were available for experiment. It is much to be regretted that the list given below includes no human subjects between the ages of twenty-six months and eight years; the writer's wholly undeserved local reputation as a vivisectionist seemed to create a stubborn unwillingness on the part of parents to supply young children for experimental work.

HUMAN SUBJECTS

Man 1. Age, 34 years. Native (Spanish-Indian) Californian. Ranch laborer in the experimenter's employ. A man of limited education, but of average intelligence for his class. He went through his trials in the stolid, unemotional manner that characterised his work in the fields. The "boss" wanted him to walk into and out of an enclosure 100 times, and he did so without asking questions or shirking his task.

Boy 7. Age, 15 years. American, of original English descent. Grocer's boy. Country school education. He was shy and nervous at the beginning of the experiment, and always seemed to be more or less affected by a fear of appearing stupid.

Boy 6F1. Age, 13 years. Father Italian, mother Swedish. Country schoolboy. He was less alert, mentally, than were his brothers, who are described below.

Boy 5F1. Age, 11 years. Brother of Boy 6F1. Country schoolboy. Volatile, alert, and rather distractible.

Boy 4F1. Age, 10 years. Brother of Boys 6F1 and 5F1. Country schoolboy. Relatively precocious, and an excellent subject.

Boy 3. Age, 10 years. Native (Spanish-Indian) Californian. Country schoolboy. Bright, but rather shy, and too nervously eager to please the experimenter.

Girl 1. Age, 10 years. American of Scotch descent. Until recently a student in the public schools of Cambridge, Mass. Her superiority of school training, and her very considerable degree of mental precocity, gave her a decided advantage over all the other human subjects, including, even, the adult Man 1.

Boy 7. Age, 26 months. American of mixed descent (son of the experimenter). At the time of the experiment he could walk; had a limited vocabulary of words, which he did not put into sentences; was able to find his way about the house; and understood many simple commands. Very quick to form new associations.

Defective Man A. Age, 45 years. Native (Spanish-Indian) Californian. Ranch laborer in the experimenter's employ. Limited school education, but had read history and uncritical works on socialism. He was a nervous, suspicious, "muddled" person, with a grievance against society in general, and a surprising fund of self-acquired misinterpretations relating to his social environment. He expressed a belief that my experiment was dangerous meddling with the human mind, and that it had some occult power of "making people crazy." His curiosity and his desire to argue matters rendered him available, but he seemed to be in constant dread of the apparatus, and always labored under a suspicion that it was not the simple structure that it pretended to be.

Defective Boy A. Age, 11 years. English. With the exception of occasional perfunctory lessons from a governess, his education was practically *nil.* He was barely able to read simple words, was unable to respect the conventions of conversation usually recognized by a child of six years, and manifested an inordinate fondness for asking questions. His cooperation varied: at times he gave attention to the experiment, and did well enough; and at times he behaved in a dull, mechanical manner. His reactions are of considerable interest.

MONKEYS

Monkey 6.[1] Age, 15 years (estimated). *Macacus cynomolgus.* About 10 years in captivity. Tame, and an excellent subject.

Monkey 4. Age, 1.5 years (estimated). *Macacus rhesus.* About 6 months in captivity. Very tame. After his 20th trial his vision became defective, so that he had difficulty in finding his way about the apparatus. His results do not appear in any of the averages.

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[1] The writer has followed Professor Yerkes' (2) method of designating male subjects by even numbers, and female subjects by odd numbers.

Monkey 3. Age, 5 years (estimated). *Macacus rhesus.* About 3 years in captivity. A truculent, untamable animal, but a fairly good subject.

Monkey 2. Age, 1.5 years (estimated). *Macacus* ——— (species undetermined). About 1 year in captivity. Timid, but exceptionally resourceful in meeting outdoor situations when he was given the freedom of the ranch. His timidity doubtless affected his behavior.

Monkey 1. Age, 1.5 years (estimated). *Macacus rhesus.* About 1 year in captivity. A comparatively stupid animal, but uniform in behavior during the experiment.

DOGS

The sixteen dogs of the following list range in age from thirty-six days to three years. With the exception of the two adults (Dogs 1 and 2), they are all descended from a common sire, the subject of my previously published "An Experimental Study of an Unusual Type of Reaction in a Dog." (3) This sire was a Boston Terrier of impure breed. The six puppies that are designated " F2 " in the list below were from a mongrel bitch of the small hound type. Their mother was unavailable for experiment. The eight puppies of the " F1 " group were from an English Setter bitch,—" Dog 1 " of the list.

Dog. 1. Age, 3 years. English Setter. Mother of dogs 3, 7, 8, 9, 11, 12, 14 and 18 (one litter). She was untrained, hence a study of her behavior under natural conditions was easily possible. It was found that whenever she sighted or scented her prey she would inhibit every visible movement of her body but a slight tremor and a wagging of her tail, and would stand thus, in a rigid attitude, for several minutes before making a final dash to seize the object of her attention. A tendency to inhibit, *momentarily*, all active movements when prey is first discovered is not limited to any special breed of dogs: it is the prolongation of this momentary inhibition that so marks the behavior of the English Setter. This reactive tendency of the mother of my puppies is of much interest for the present investigation.

Dog 2. Age, 1 year (estimated). Great Dane-mongrel. His tendency to look to his master for cues to action marked him as characteristically different from all the other dogs of my experiment. The other dogs sought cues to action in the situation, and were not so much affected by my presence.

Dog 4F2. Age, 116 days. Boston terrier-mongrel.
Dog 6F2. Age, 109 days. Boston terrier-mongrel.
Dog 3F1. Age, 102 days. Boston terrier-English setter.
Dog 8F1. Age, 95 days. Boston terrier-English setter.
Dog 5F2. Age, 88 days. Boston terrier-mongrel.
Dog 7F1. Age, 81 days. Boston terrier-English setter.
Dog 10F2. Age, 74 days. Boston terrier-mongrel.
Dog 9F1. Age, 67 days. Boston terrier-English setter.
Dog 11F1. Age, 60 days. Boston terrier-English setter.
Dog 12F1. Age, 53 days. Boston terrier-English setter.
Dog 14F1. Age, 46 days. Boston terrier-English setter.
Dog 13F2. Age, 43 days. Boston terrier-mongrel.
Dog 16F2. Age, 43 days. Boston terrier-mongrel.
Dog 18F1. Age, 36 days. Boston terrier-English setter.

CATS

Cat 1. Age, 1 year. Manx. This animal was reared in the Harvard Psychological laboratory, and enjoyed the further distinction of having been one of Doctor Berry's (4) subjects in his studies of imitation. Although my apparatus has no technical resemblance to that used by Doctor Berry, Cat 1 explored it carefully, and for several trials persisted in her efforts to claw at imaginary loops of string beyond the meshes of the wire netting. Her close attention to the apparatus situation, and her remarkable intelligence (as compared with that of common cats) was of much interest.

Cat 2. Age, 1 year. Common house cat. Co-operated well.
Cat 3. Age, 1 year. Same as Cat 2 except in sex.
Cat 5. Age, 56 days. Common cat. Co-operated well.
Cat 7. Age, 70 days. Common cat. Timid and sluggish.

HORSE

Horse 2. Age, 8 years. Gelding of western breed. Carriage horse. In view of the very poor showing made by this animal, the stableman's belief in his " smartness " is of some interest. On one occasion the writer was driving this horse at night, over an unfamiliar network of roads. The horse was guided in a wrong direction on the way home, and the writer became quite disoriented. When the horse was given a loose rein he traced the way back without error, although he had been over the various roads involved less frequently than had his master.

III. TABULATION AND PRELIMINARY ANALYSIS OF RESULTS

It will be remembered that each of the subjects was given 100 trials, and that during each of these trials one, but only one, of the four exit doors was capable of being opened. It will be further remembered that this "unlocked" door varied from trial to trial. Thus, if Door 3 were unlocked for any present trial it would surely be locked for the next trial. It is apparent, therefore, that any subject who avoided, during each present trial, the unlocked door of the immediately preceding trial, was apt to effect his escape during his 100 trials by trying the various exit doors 200 or 201 times: 200 times if he did not try all four doors during his first trial, otherwise, 201 times.

Again, any subject who tried the various doors without reference to the ever varying one impossible door as such, or as a preferable door to try on account of its having just afforded the escape, would be apt to effect his escape from the apparatus necessary 100 times by trying the various exit doors 250 times.

The "average" number of efforts to open exit doors would be affected by any of the following factors:

(1) This number would be decreased by a tendency to try first, on entering the apparatus for a trial, the exit door that had been most remotely (in time, with reference to the present trial) an unlocked door. This, in spite of the fact that the experimenter followed an irregular order in selecting exit doors for unlocking.

(2) It would be increased by a tendency to prefer, as first choice of door to be tried during a given trial, the unlocked door of the immediately preceding trial.

(3) It would be increased by a tendency to make more than one separate effort to open the same exit door during a given trial.

In table 1, I have tabulated the total number of separate efforts to open exit doors manifested by each of the various subjects during his 100 trials. In making current observations of my subjects' behavior I recorded as a separate effort to open an exit door the total activity of a subject from the time he attacked an exit door until he left its immediate vicinity. For example, during his second trial Dog 18F1 went to Door 4 and clawed it for several minutes, then turned away from this door and wandered about the apparatus; one effort to open an exit door was recorded. Then he returned to Door 4 and again spent some time in alternately clawing and barking at it; when he left the door a second time a second effort was recorded. He returned to it, tried it and left it a third and a fourth time before attacking another door, hence his first four separate activities, all of which were definitely directed against the same unyielding door, were recorded as four separate efforts to open exit doors.

With the above in mind the reader will be able to obtain a general orientation concerning the value of the situations for each of the various subjects.

TABLE 1

Subject.	Age.	No. of efforts to open exit doors.
Man 1	34 years	200
Boy 7	15 years	193
Boy 6F1	13 years	201
Boy 5F1	12 years	216
Boy 4F1	10 years	194
Boy 3	10 years	211
Girl 1	10 years	183
Boy 2F1	8 years	216
Boy 1	26 months	315
Man A	45 years	217
Boy A	11 years	237
Monkey 6	15 years	275
Monkey 4	1.5 years	291
Monkey 3	5 years	278
Monkey 2	1.5 years	272
Monkey 1	1.5 years	278
Dog 1	3 years	324
Dog 2	1 year	302
Dog 4F2	116 days	346
Dog 6F2	109 days	329
Dog 3F1	102 days	284
Dog 8F1	95 days	378
Dog 5F2	88 days	304
Dog 7F1	81 days	357
Dog 10F2	74 days	427
Dog 9F1	67 days	389
Dog 11F1	60 days	358
Dog 12F1	53 days	307
Dog 14F1	46 days	413
Dog 13F2	43 days	314
Dog 16F2	43 days	376
Dog 18F1	36 days	438
Cat 1	1 year	358
Cat 2	1 year	378
Cat 3	1 year	320
Cat 7	70 days	406
Cat 5	56 days	368
Horse 1	8 years	461

Discussion of Table 1. In the light of analyses that are to follow, this table has a largely negative value. It shows how misleading a single objective measure of ability to profit by experience may be. For example, the three-year old mother of the F1 puppies (Dog 1) made 324 separate efforts to open exit doors during 100 trials, whilst her fifty-three-days old puppy (Dog 12F1) has a record of only 307 efforts to open doors. Her record is also greater than that of three of the other puppies (Dogs 3F1, 5F2, and 13F2). Table 1 also shows that immature Monkey 2 has a lower record than either of the two adult monkeys; and that the record of mature Cat 2 exceeds that of fifty-six-days old Cat 5 by ten efforts to open doors. In the case of the monkeys, the apparent inconsistency of ontogenetic findings becomes all the more striking when we take into account the fact that at 1.5 years of age the Macacque is scarcely half-grown, and sexually immature.

When we enter upon a discussion of the different modes of searching for unlocked doors, and attempt to isolate the specific reactive tendencies to which these may be attributed, it will be seen that a genetically superior reactive tendency may lead, in some of its manifestations, to an actual increase in number of efforts to open doors. For the present, however, it is desirable to subject the data contained in table 1 to further analysis in order to discover whether or not there is a general tendency for increasing age and phyletic position to decrease the number of efforts to open doors. To this end the various subjects will be divided into age and phyletic groups, and the averages for each of these groups will be compared.

Since the results obtained from the normal human subjects whose ages range from eight to thirty-four years do not present individual variations from their general average which can be clearly traced to age differences, these eight subjects will be included in a single group. The two defective human subjects—Man A and Boy A—cannot properly be classed together, hence their individual results will appear separately in the table of averages (table 2, below). The human infant (Boy 1), the monkey whose failing vision affected his behavior (Monkey 4), and the horse should, for obvious reasons, appear separately in a table of averages. The mature dogs and mature cats each form an age group, as do also the kittens. In the case of the puppies, their considerable number enables us to form two age groups: the thirty-six-to-seventy-four days-old puppies and the eighty-one-to-one hundred and sixteen-days-old puppies.

TABLE 2

Groups of subjects	No. of subjects in each group	Average age for entire group	Average number of efforts to open exit doors
8-to-34-years-old normal human......	8	14 years	201.75
Defective man A..................	1	45 years	217.00
Defective boy A...................	1	11 years	237.00
Infant Boy 1.....................	1	26 months	315.00
Mature monkeys...................	2	10 years	276.50
Immature monkeys................	2	1.5 years	275.00
Defective Monkey.................	1	1.5 years	291.00
Mature dogs.....................	2	2 years	313.00
81-to-116-days-old puppies..........	6	98.50 days	333.00
36-to-74-days-old puppies.............	8	52.75 days	377.75
Mature cats.......................	3	1 year	352.00
Kittens..........................	2	63 days	387.00
Horse...........................	1	8 years	461.00

Ontogenetic aspects of table 2. The normal humans, the dogs and the cats manifest a tendency toward increase in number of efforts to open doors with decrease in age. This is especially prominent in the case of the human infant, whose record exceeds that of the average for the older normal human subjects by 56.13 per cent. Defective Man A, whose record appreciably exceeds that of the eight-to-thirty-four-years-old normal human subjects, would doubtless have presented a much higher record had he not manifested a marked tendency to make first choice of the most remotely unlocked door during each present trial. It may be said, indeed, that his total modes of adjustment to the situations of the experiment were, on the average, of a lower type than those manifested by defective Boy A, whose record places him below Man A in the table 2 list. This additional evidence of the unreliability of the findings of tables 1 and 2 as measures of intelligence will be brought out more explicitly in sections IV and V.

A general knowledge of the marked differences that obtain between the behavior of an adult monkey and that of a half-grown one would lead the student of behavior to expect that under similar conditions no year-and-a-half old macacque would find the unlocked door one hundred times with fewer efforts than an adult macacque. The but slightly lower record of the two half-grown monkeys is, therefore, of some interest. Here, too, an explanation is to be found in differences of reactive tendency which require, for genetic evaluation, more than a single standard of measurement.

Phylogenetic aspects of table 2. A comparison of the various adult groups shows that in order of ability to avoid useless efforts to open exit doors the older normal human subject stands first, the mature monkeys second, the dogs third, the cats fourth, and the horse fifth. Table 1 shows that the horse has the highest individual record of efforts to open doors that is manifested by any subject, regardless of age.

It is of some interest that twenty-six-months-old-Boy 1 made a greater number of efforts to open exit doors than did any of the following subjects: All other human subjects, all of the monkeys, and dogs 2, 3F1, 5F2, 12F1, 13F2. If mere ability to avoid useless activities were a measure of intelligence, this finding would imply that my son was less intelligent at twenty-six months than was one of my forty-three-days-old puppies (Dog 13F2). In view of the fact that at the time of the experiment Boy 1 gave unmistakable evidence of having "free ideas" (5), this is an absurd implication.

IV. DETERMINATION OF THE DIFFERENT MODES OF ADJUSTMENT MANIFESTED

It will be remembered that the conditions of the experiment require the subject who seeks escape from the apparatus merely to search for an unlocked door until he finds one. The present chapter seeks to classify the different modes of searching for this ever-varying unlocked door.

In order to facilitate the descriptions that follow, the value of each of the four exit doors in a given trial-situation will be designated by one of the following terms:

The impossible door. For any present trial this is the unlocked door of the immediately preceding trial; hence it is an inferentially impossible door of exit during the present trial for any subject who is able to appreciate that no one door is ever an unlocked door in two successive trials.

The possible doors. No subject is able, during a given trial, to tell with certainty which one of three exit doors will yield to pressure until he tries it. Of these three inferentially possible doors of exit, two are actually locked, and one is unlocked. We shall speak, therefore, of "locked possible doors" and an "unlocked possible door."

The intention of our investigation requires a division of all the reactions of the subjects into two groups, only one of which can enter into the tables. These groups are:

(1) *Unclassified reactions.* This group includes all reactions which led to the discovery of the unlocked door before all three possible doors were tried, and which did not include more than a single effort to open any given door during the trial. I have rejected from the tables as "unclassified" all reactions which met the above conditions, even though such a reaction included an effort to open the impossible door. This is justified, I believe, by the fact that none of the animal subjects seemed to have a consistent awareness of the impossible door as such. The description of classified reactions will disclose an additional reason for this exclusion.

(2) *Classified reactions.* To fall within this group a reaction must meet one of the following conditions: (a) Efforts to open each of the three possible doors; (b) more than one separately continuous effort to open a given door during the trial. For example, if during a present trial, door 3 were the unlocked door of the immediately preceding trial and door 2 the unlocked door of the present trial, a reaction which could be tabulated according to any of the following formulae would fall within the classified group: Efforts to open exit doors 4, 1, 2 in the order given; or exit doors 1, 4, 1, 2; or exit doors 4, 4, 1, 2, etc.

The classified modes of searching for the unlocked door were found to belong to five objectively different general types, which may be described as follows:

Type A. All three possible doors tried, *once each;* no effort made to open the impossible door.

This is the most adequate possible type of classified reactions.

Type B. All four exit doors are tried, once each, and in an irregular order.

Type C. This reaction can occur only when the door to the extreme right (Door 4), or the one to the extreme left (Door 1) is the unlocked door. It involves trying each of the four exit doors once, and in order from left to right or from right to left, according as Door 4 or Door 1 is the unlocked door. Thus, if Door 1 be unlocked, the subject tries the doors in the following order: 4, 3, 2, 1.

Type D. More than a single continuous effort to open a given door during the trial; but between separate efforts to open the same door there must be an effort to open some other door. Thus, the subject tries doors in the following order: 4, 1, 4, 3; or 4, 1, 2, 4, 3, etc.

Type E. This type includes various highly inappropriate modes of seeking escape from the apparatus which might be classed as separate types of reaction were it not that when collectively treated as a unit in the distribution curve they are seen to belong to a single general type. The various forms of Type E reactions are,—(a) during a given trial the subject tries a door, leaves it, then returns to it and tries it a second time *without having tried any other door;* (b) during a given trial the subject attacks a group of two or three locked doors two or more times in a regular order; (c) during a given trial the subject, without falling into either of the above two errors of reaction, persistently avoids an exit door, so that he makes at least seven separate efforts to open exit doors before effecting his escape.

It is especially important to gain a clear understanding of the objective characteristics of the classified types of reaction described above, since they will appear as units in all of the analyses that are to follow. Table 3, given below, contains characteristic examples.

TABLE 3

EXAMPLES OF CLASSIFIED REACTIONS

Type A	*Type B*	*Type C*	*Type E*	*Type E*
4, 2, 1	4, 2, 3, 1	4, 3, 2, 1	4, 3, 4, 1	3, 3, 1 (sub-type a)
2, 4, 1	3, 4, 2, 1	1, 2, 3, 4	2, 3, 4, 3, 2, 1	4, 2, 2, 2, 2, 1 (sub-type a)
	2, 3, 4, 1		2, 4, 3, 2, 1	4, 2, 4, 2, 1 (sub-type b)
				3, 4, 2, 3, 4, 2, 3, 4, 2, 1 (sub-type b)
				4, 3, 2, 4, 2, 3, 1 (sub-type c)
				3, 4, 2, 4, 3, 2, 3, 4, 1 (sub-type c)

EXPLANATION OF TABLE 3—Each horizontally arranged group of figures describes a single trial; and each figure in such a group refers to an exit door tried. Thus, "4, 2, 3, 1" is descriptive of a trial during which the subject tried first to open door 4, following which he tried doors 2, 3 and 1 in the order given. The last figure in each horizontally arranged group refers to the exit door which afforded escape when the subject pushed against it.

The examples under Type A obtain their true significance only when we assume that they describe trials during which door 3 was the impossible door.

TABLE 4

Distribution of Classifiable Reactions Manifested by each Subject During His Series of 100 Trials

Subject.	Age.	No. of classified reactions.	Distribution of classified reactions in percentages of each subject's total number of the same.				
			Type A %	Type B %	Type C %	Type D %	Type E %
Man 1	34 years	28	m82.14	17.86	0.00	0.00	0.00
Boy 7	15 years	27	m70.37	25.92	0.00	0.00	3.70
Boy 6F1	13 years	26	m69.23	23.08	7.69	0.00	0.00
Boy 5F1	12 years	33	m84.85	15.15	0.00	0.00	0.00
Boy 4F1	10 years	26	m76.92	23.08	0.00	0.00	0.00
Boy 3	10 years	31	70.97	19.35	3.23	6.45	0.00
Girl 1	10 years	21	m85.71	14.29	0.00	0.00	0.00
Boy 2F1	8 years	34	m70.59	17.65	5.88	5.88	0.00
Boy 1	26 months	38	15.79	5.26	18.42	26.32	m34.21
Man A	45 years	29	48.28	m51.72	0.00	0.00	0.00
Boy A	11 years	40	m62.50	7.50	30.00	0.00	0.00
Monkey 6	15 years	36	19.44	22.22	19.44	m27.78	11.11
Monkey 3	5 years	39	23.08	23.08	20.51	m30.77	2.56
Monkey 4	1.5 years	39	17.95	15.38	12.82	m28.21	25.64
Monkey 2	1.5 years	34	14.71	14.71	m41.18	14.71	14.71
Monkey 1	1.5 years	37	16.22	m29.73	21.62	21.62	10.81
Dog 1	3 years	40	12.50	12.50	0.00	30.00	m45.00
Dog 2	1 year	42	11.90	30.95	0.00	m38.10	19.05
Dog 4F2	116 days	43	11.63	16.28	16.28	18.60	m37.21
Dog 6F2	109 days	48	16.67	27.08	20.83	6.25	m29.17
Dog 3F1	102 days	31	25.81	m38.71	12.90	0.00	22.58
Dog 8F1	95 days	42	4.76	16.67	0.00	26.19	m52.38
Dog 5F2	88 days	42	7.14	16.67	m28.57	19.05	m28.57
Dog 7F1	81 days	51	17.65	9.80	9.80	29.41	m33.33
Dog 10F2	74 days	48	16.67	10.42	2.08	33.33	m37.50
Dog 9F1	67 days	52	15.38	9.62	13.46	23.08	m38.46
Dog 11F1	60 days	45	20.00	4.44	m33.33	13.33	28.89
Dog 12F1	53 days	35	11.43	20.00	31.43	0.00	m37.14
Dog 14F1	46 days	53	7.55	11.32	5.66	30.19	m45.28
Dog 13F2	43 days	41	17.07	24.39	12.20	17.07	m29.27
Dog 16F2	43 days	42	14.29	0.00	11.90	35.71	m38.10
Dog 18F1	36 days	48	12.50	4.17	6.25	25.00	m52.08
Cat 1	1 year	49	12.24	m30.61	10.20	18.37	28.57
Cat 2	1 year	42	4.76	11.90	0.00	33.33	m50.00
Cat 3	1 year	36	8.33	13.89	0.00	33.33	m44.44
Cat 7	70 days	53	7.55	1.89	0.00	22.64	m67.92
Cat 5	56 days	51	5.88	19.61	0.00	5.88	m68.63
Horse 1	8 years	50	8.00	4.00	2.00	24.00	m62.00

Discussion of table 4. The arrangement of the subjects in phyletic groups, and their arrangement within these groups according to age, enable us to gain from table 4 a general idea of the behavior of individuals as conforming to or varying from that which might be expected to obtain at a given position in the ontogenetic and phylogenetic scales. The highest percentage for each subject is marked by an m in the table in order to render it easy for the reader to tell at a glance the type of reaction most frequently manifested by any subject.

The older normal human subjects and defective Boy A are seen to have "preferred" Type A reaction. Defective Man A preferred Type B, and the infant Boy 1 preferred Type E.

The mature monkeys and one of the immature monkeys (No. 4) have their highest percentages in the Type D column, whilst immature Monkeys 2 and 1 have their highest percentages in Type C and Type B columns respectively. In view of the fact that reactions of Types B and C are more adequate modes of adjustment than is the Type D reaction, this finding is of considerable interest, as will be shown in the next chapter, where a psychological interpretation of these types of reaction is attempted.

Of the twenty-two animal subjects below the primates, only five preferred any other type of reaction to Type E. These exceptional cases require the following explanation. Dogs 2 and 3F1 were obviously more intelligent in meeting the situations of everyday life than were their fellows. Dogs 5F2 and 11F1, who manifested a preference for Type C reactions, seem to have fixed upon this systematic mode of searching for the unlocked door much earlier in the experiment than is usually the case with dogs: after a variable number of trials (usually from 300 to 600) the average dog will manifest 100 per cent of Type C reactions.

Cat 1, who manifested a preference for Type B reactions, has already been described as an exceptionally intelligent animal (p. 43).

The evidences of marked individual differences contained in table 4 must be looked upon, of course, as a serious obstacle to any effort to deal with the results in terms of age and phyletic averages. It is obvious that such averages, to be available for conclusive interpretations, would have to be obtained from a far greater number of subjects for experiment than could be practically used in an exploratory investigation. However, since the averages obtainable from the above table may serve to attract attention to some interesting possibilities in genetic psychology, the writer is justified, I believe, in presenting them.

TABLE 5

DISTRIBUTION OF CLASSIFIED REACTIONS ACCORDING TO AGE AND PHYLETIC AVERAGES

Subjects.	Average age.	Total classified reactions.	Distribution of classified reactions in percentages of same.				
			TypeA %	TypeB %	TypeC %	TypeD %	TypeE %
Older human (8).........	14 years	226	76.11	19.47	2.21	1.77	0.44
Man A (1)..............	45 years	29	48.28	51.72	0.00	0.00	0.00
Boy A (1)..............	11 years	40	62.50	7.50	30.00	0.00	0.00
Infant (1)..............	26 months	38	15.79	5.26	18.42	26.32	34.21
Mature monkeys (2)......	10 years	75	21.33	22.67	20.00	29.33	6.67
Immature monkeys (2)....	1.5 years	71	15.49	22.53	30.99	18.31	12.68
Mature dogs (2)..........	2 years	82	12.20	21.95	0.00	34.15	31.71
Older puppies (6)........	98.50 days	357	13.61	19.84	14.79	17.51	34.24
Younger puppies (8)......	52.75 days	364	14.26	10.16	13.74	23.08	38.76
Mature cats (3)..........	1 year	127	8.66	19.68	3.94	27.56	40.16
Kittens (2)..............	63 days	104	6.73	10.58	0.00	14.42	68.27
Horse (1)...............	8 years	50	8.00	4.00	2.00	24.00	62.00

Discussion of table 5. The significance of the findings of the table becomes more apparent when they are plotted in distribution curves, as shown in figure 3 on the opposite page. Reference to these curves will disclose the following facts concerning the general effects of age and phyletic position on mode of adjustment:

(1) The curve for the older human subjects attains its greatest height at point A, whence it descends rapidly to point B, thence to point C, where it closely approximates the base (zero) line. From C to D to E the curve descends continuously.

(2) The infant's curve is relatively low at point A, whence it descends abruptly to point B, after which it ascends continuously and rather sharply until it reaches its maximum height at E.

(3) Defective Man A's curve *ascends* from A to B; from B it descends directly to the base line, with which it is coincident at points C, D and E.

(4) Defective Boy A's curve descends sharply from A to B, undergoes a marked secondary rise at C, and from there passes to the base line, with which it is coincident at D and E.

(5) The mature monkey's curve ascends slightly from A to B; descends slightly from B to C; attains its maximum height at D, from which point it descends sharply to E, where it is near the base line.

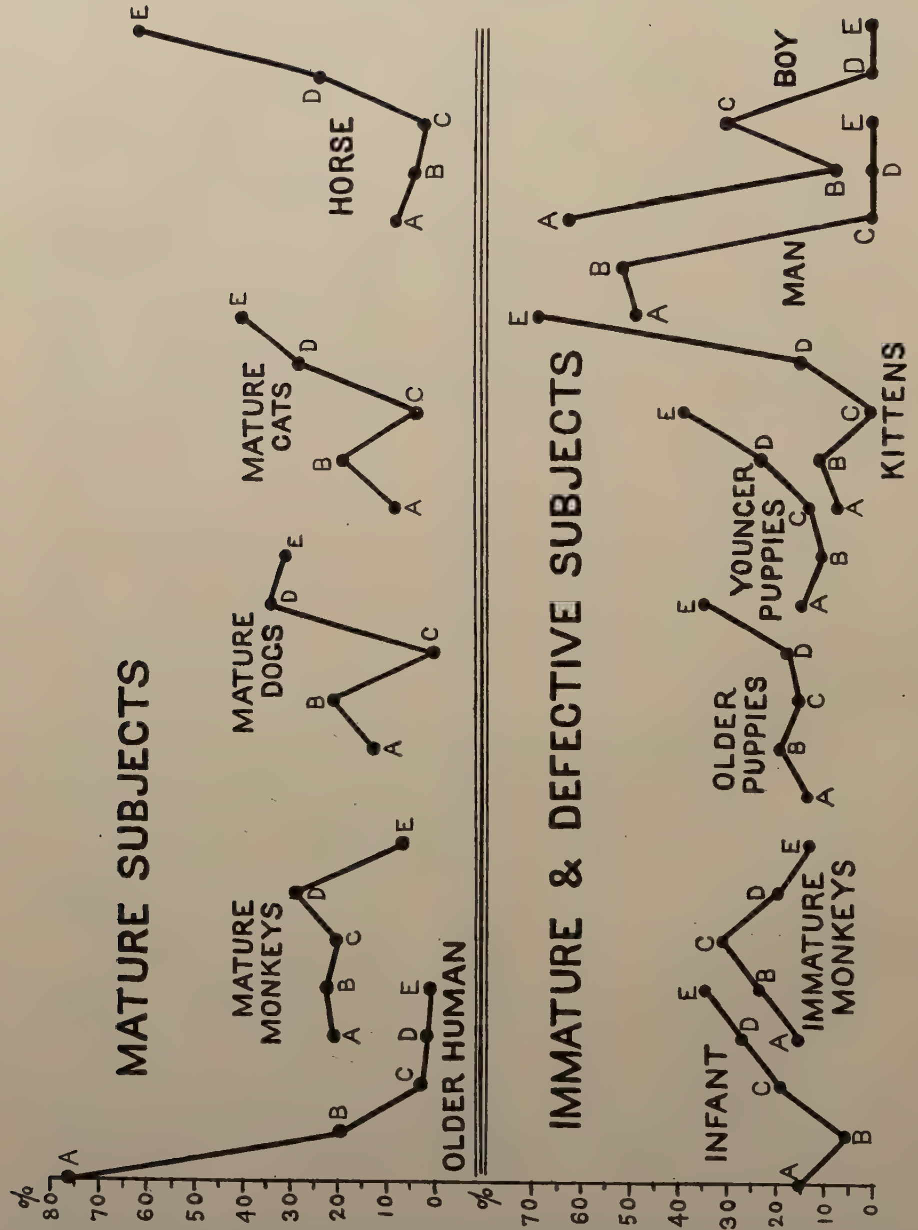

FIGURE 3—Curves showing the distribution of classified reactions. "A," "B," "C," D" and "E" refer to the types of classified reactions described in the text and the dots immediately beneath these letters indicate the percentages of the various reactions thus designated.

(6) The immature monkey's curve differs radically from that of the mature monkey's in that it ascends continuously and rather sharply from A to B to C, attaining its greatest height at C; the descent from C to D to E is likewise sharp and continuous. The curve is lower at A and higher at E than is the mature monkey's curve at these points.

(7) The mature dogs' curve makes a considerable ascent from A to B; drops to the base line at C, from which it ascends to its maximum height at D; and makes a slight descent from D to E. In view of the fact that with prolonged experience the dog tends to manifest C reactions only, the absolute absence of these reactions, as reflected by the position of C in their curve of distribution, is of considerable interest.

(8) The older puppies' curve ascends from A to B; descends slightly from B to C, after which it ascends slightly to D; and ascends sharply to attain its maximum height at E.

(9) The younger puppies' curve, when compared with that of the older puppies', affords us material of some value for ontogenetic interpretations, since the averages for these two groups include a considerable number of subjects. In both curves, A is relatively near the base line, but in the younger puppies' curve there is a descent from A to B, as compared with an A to B ascent in the older puppies' curve. From C to E both curves ascend continuously, but the younger puppies' curve makes a sharper ascent, and is higher at E.

(10) The mature cats' curve bears a striking resemblance to that of the mature dogs, the only points in which they are essentially different being as follows: (a) The mature cats' curve is slightly above the base line at C, whilst in the case of the mature dogs it is coincident with the base line at C; (b) the mature cats' curve ascends from D to E, attaining its maximum height at E, whilst the mature dogs' curve slightly descends from D to E. It is quite possible that averages for large number of cats and dogs would efface these differences. It may be stated, however, that the writer's experience with these two classes of subjects leads him to believe that the average cat is more prone to manifest the Type E reaction than is the average dog.

(11) The kittens' curve has many points of similarity with the older puppies' curve; it ascends from A to B; descends from

B to C, from which point it ascends to D; from D it ascends very sharply to E, where it attains its maximum height

(12) The horse's curve is near the base line until it reaches C, from which it ascends sharply to D; from D it makes a still sharper ascent to E, the point of its maximum height.

V. INTERPRETATIONS OF RESULTS. CONCLUSIONS.

It has been shown, I believe, that the higher mammals manifest striking differences of modes of trial and error activity, and that these differences cannot be adequately expressed in terms of rapidity of habit formation alone. The results indicate, also, the need of intensive behavior-studies along hitherto unexplored lines of investigation. The present chapter seeks to relate the types of reaction that have been discussed in the foregoing to inferred reactive tendencies, and thus to assign psychological values to the curves of distribution shown in figure 3. This attempt must be prefaced, however, by a statement of the viewpoints from which the interpretations that follow have been undertaken.

While the Comparative Psychologist has been almost exclusively concerned with a single psychological value—associative memory[1]—the field of Psychopathology has been revolutionized by a group of men who have shown that behavior is determined by a vast complexus of reactive tendencies which demand isolation and psychological estimation. These men, notably Freud (6), Jung (7), Bleuler (8), and Adolph Meyer (9), have opened up, by their activities along highly specialized lines of interest, new possibilities for the development of genetic psychology. They have shown, by implication, at least, that genetic psychology should not be solely concerned with the developmental history of the specifically adaptive instincts and of the mature human ability to think according to the traditional canons of logic. The dancing mouse's acquisition of a habit of selecting a spatially variable white labelled avenue of escape from pain, and the mathematician's solution of a problem in infinitesimal calculus are alike to be looked upon as end-products of reactive tendencies which have been variously subjected to the selective, suppressive, fixative and other corrective influences of experience. We must have knowledge, therefore, of the genetic relationships, not only of the adequately adaptive end-products in behavior, but of the reactive tendencies that lead to these end-products.

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[1] The writer assumes that functional studies of the sense organs belong to Physiology rather than to Psychology.

The present investigation becomes intelligible only when account is taken of the fact that it seeks to deal with the fundamental factors on which adaptation depends, rather than with the ultimate effects of experience on behavior. Figure III depicts, therefore, roughly determined curves of reactive tendency, and not curves of learning. Since their value as curves of reactive tendency will depend on the accuracy with which the objective facts are translated into terms of psychic entities, we are confronted by the difficult task of establishing an objective criterion of the subjective. How may we recognize a reactive tendency in the behavior of our subjects? During the interpretations that follow, a tentatively constructed criterion will be adhered to: *A mode of adjustment which appears, disappears and reappears consistently with ascent or descent of the age and phyletic scales may be looked upon as an expression of a definite reactive tendency.*

If this criterion be accepted, a tremendous amount of detailed investigation will be required to establish conclusively the existence of even a few reactive tendencies as biological entities.

With the above in mind as a qualification of what follows, we may proceed to an interpretation of results by first presenting a summary of the values for reaction contained in the experiment:

(1) All of the subjects brought to the formal experiment a more or less definite awareness of the four exit doors as possible means of escape from the apparatus, hence the demand for adjustment was essentially contained in the mere necessity of clawing, scratching or pushing at one or more previously mobile objects (all of the exit doors were left unlocked during the preliminary training) until activity proved successful.

(2) Without exception, all of the subjects gave definite evidence of trying for success (escape from the apparatus) until success was attained.

(3) For every subject a considerable percentage of trials led to more or less unsuccessful activity (trying locked doors).

(4) In every case the individual trial was terminated by a definitely directed activity (trying the unlocked door).

(5) The relation of every present trial to its immediate predecessor was such as to exact a penalty of non-success for trying the unlocked door of the immediately preceding trial.

(6) During a given trial, a second or third, etc., effort to open a particular door was invariably unsuccessful: a door which would not yield to a single, definitely directed attack during a given trial could not possibly be opened by the subject during that trial.

(7) The various doors were discriminable, one from another.

Under the conditions just enumerated, the various types of reaction that we have isolated are capable of the following psychological interpretations:

Type A. To conform to this type, the reaction must include a single, definite effort to open each of the three inferentially possible doors, and must not include an effort to open the inferentially impossible door. It will be remembered that the impossible door varied from trial to trial.

Now it is evident that only an awareness of the impossible door as such would enable any subject to manifest appreciably more than 50 per cent of Type A reactions out of his total number of classified reactions. If the impossible door were of indifferent value for reaction, either as impossible or as the object of the subject's latest successful activity, and if during no trial the subject were to make more than a single effort to open any one door, his record would tend to show 50 per cent of Type A reactions and 50 per cent of Type B or C reactions. Of course, a preference for the impossible door or a tendency to make more than a single continuous effort to open a particular door during a given trial would impair the subject's chance of approximating even 50 per cent of Type A reactions.

What reactive tendency, then, would lead to more than 50 per cent of Type A reactions? It is obvious that this cannot be the primitive tendency to reduce diffuse activity-impulses to a definite attack upon a single object. The situation rendered it impossible for any subject to associate a simple object with successful activity and to obtain thereby a formula for invariable success. On the other hand, the establishment of a simple negative association was not sufficient to enable any subject to avoid the impossible door. This spatially varying object-to-be-avoided could clearly obtain its true value for reaction only among the subjects who were able to elaborate a succession of previous experiences in such a manner as to associate, at each trial, the door last opened with an awareness equivalent to "during any present trial the door last opened is apt to be impossible as a means of exit." In other words, there would have to be an association in which one of the elements would be a complexly derived awareness of a principle deterrent to the activity involved in trying the unlocked door of the immediately preceding trial. The conscious avoidance of the impossible door as such may therefore be looked upon as due to a tendency to make rational inferences from a sequence of past experiences. For convenience of statement it will be referred to hereafter as "*the rational inference tendency.*"

Type B. This reaction involves trying all four doors, but once each, and in an irregular order.

From the normal adult human viewpoint this adjustment contains but one error, viz., the inferentially and actually useless effort to open the impossible door. In cases where there is clearly apparent a perception of the impossible door principle (i. e., where there is given a record of appreciably more than 50 per cent of Type A reactions), the manifestation of Type B reactions may be assigned either to mere inattention or to lapse of memory, or to the necessity of falling into the impossible door error a certain number of times before an awareness of the principle can be obtained. If we exclude these cases, the Type B reaction may be looked upon as an expression of a high type of searching tendency. Although it shows a lack of modification by the higher tendency to make rational inferences, it is of much significance as showing the absence of modification by the lower tendencies to which we shall ascribe reactions of the C, D and E types. Of course the inclusion of an effort to open the impossible door may be due, in a certain number of cases, to the interference of a tendency to associate the last successful activity with the impossible door, in which case the searching tendency is not the sole reactive factor. But since we are dealing only with the reactive tendencies that precede the establishment of definite and habitual associations, we may, for convenience, refer to Type B reactions as due to "the unmodified searching tendency." This, of course, only when the number of Type A reactions is so small as to exclude the possibility that mere inattention or forgetfulness have interfered with an adequate expression of the rational inference tendency.

Type C. This highly interesting mode of adjustment can occur, as has been explained, only when Door 1 or Door 4 is the unlocked door for the trial. It involves merely the act of trying (1) Doors 1, 2, 3 and 4 but once each and in the order given when Door 4 is the unlocked door, or (2) doors 4, 3, 2 and 1 but once each and in the order given when door 1 is the unlocked door. The habit of starting at either the first or the last door from the left and working down the line of doors, striking each as it is passed until an unlocked door is found, deserves, in itself, a far more extensive investigation than it has thus far received. My observations of the higher infra-human mammals, of children and of mentally defective or diseased persons lead me to believe that in this mode of adjustment we have the expression of a reactive tendency which has extensive genetic relationships, and which can be more easily recognized in behavior than can any other reactive tendency of which we have knowledge. In the discussions that follow Type C reactions will be referred to as due to "the tendency to adopt stereotyped modes of searching."

Type D. This reaction involves the error of making more than one separate, continuous effort to open a given door during the same trial, but always with an interruption of such repetitions of activity by an interval of effort to open one or more of the other doors. Since this mode of adjustment is objectively continuous with a form of Type E reaction (sub-type c, described below), and yet clearly should not be made to include the latter, I have excluded from Type D all reactions involving more than six separate efforts to open doors during a given trial.

A characteristic example of the Type D reaction will render its interpretation more intelligible. During his fortieth trial Dog 16F2 made a vigorous effort to open Door 1, which was locked; failing in this effort, he tried to open Door 2, which also baffled him in his efforts to escape. Then he returned to Door 1 and made a second effort to open it by giving it two or three feeble scratches, after which he tried Doors 3 and 4, the latter of which yielded to his attack.

Anybody who has ever sought vainly, and with some irritation, a lost collar button, will readily appreciate the inner significance of this behavior. One looks into every likely nook and corner, then remembers that on previous occasions he has discovered lost articles in a drawer which is seldom used because of its tendency to "stick." The drawer is opened and is found to be quite empty; one turns away and looks elsewhere, only to return in a moment to the empty drawer and again to open it in a stupid, unthinking manner. The impulse to open the drawer seems to have subsided with the first failure, only to come surging back with most inappropriate persistence.

Type D reactions will hereafter be referred to as due to "the searching tendency modified by recrudescent motor impulses."

Type E. This type includes several different modes of behavior which have a common objective characteristic, viz., automatism. That is, the subject behaves in a relatively implastic, unadaptive manner. The objective characteristics of the various sub-types may be reviewed as follows:

Sub-type a. The subject makes two or more successive but definitely separate attempts to open the same door during a given trial. Thus he tries Door 3, finds it locked, turns away from it, returns to this same door and makes a second effort to open it without having tried any other door in the meantime, etc. In view of the fact that in the majority of cases such persistence in returning to the same door during a given trial could not be attributed to the recency with which it had afforded escape (as compared with the recency with which the other doors had afforded escape), we are justified in assuming, I believe, that the sub-type a reaction is an expression of the unmodified primitive tendency to repeat an activity, once it is begun, until it leads quite definitely to pain or success.

Sub-type b. During a given trial the subject tries a group of locked doors two or more times in an unvarying order. Cat 1's ninety-fifth trial well illustrates this mode of adjustment. When this animal entered the apparatus to meet, for the ninety-fifth time, a situation which merely required that she find the one unlocked door, she tried the exit doors in the following order: *2-1-4 - 2-1-4 - 2-1-4* - 2-1-3. I have italicised each of three exactly similar cycles of activity in order to bring out more clearly the characteristic features of a mode of adjustment which seemed to spring from a persistent impulse to try Doors 2, 1 and 4 again and again, in an unvarying order. Now during her experience with ninety-four previous trials she had found Door 3 unlocked twenty-three times, Door 2 twenty-four times, Door 1 twenty-four times and Door 4 twenty-three times. It seems that no elements in these experiences were sufficient to awaken an impulse to try Door 3 after she had given definite expression to the first impulses to try Doors 4, 1 and 2; and that these latter impulses continued to reassert themselves as a connected whole until a break in the fourth cycle of activities led her to try Door 3 instead of Door 4.

Sub-type c. The subject, having avoided a given exit door during a trial, continues to avoid it while the other doors are tried at least six times and these six or more efforts to open the other doors do not contain errors of either the sub-type a or sub-type b kind. The ninety-fourth trial of Dog 9F1 affords an example of this behavior. On entering the apparatus she went to door 3, raised her paw as if about to strike it, then desisted without having touched the door. Following this she tried the doors in the following order: 1-2-4-2-1-2-4-1-2-3. The effect of the initial inhibition of the impulse to strike door 3 is apparent, I believe, in the reaction-formula just given; this inhibition persisted, so that whenever the subject passed door 3 she failed to include it in her list of doors to be tried. If the order in which she tried the other doors had suggested a mere perseveration of active motor impulses, or if she had tried these doors less than six times, the writer would not have felt justified in tabulating her reaction as belonging to sub-type c.

In view of the fact that many of the reactions manifested by the infant and the animals presented the characteristics of all three Type E sub-types, it has been found more satisfactory to deal with all Type E reactions as a unit for analysis and interpretation. This is justified, I believe, by the fact that the three sub-types are alike interpretable in terms of a single general tendency, viz., perseveration of impulses. Finer analyses of behavior than are possible in the present investigation would doubtless show that we are here dealing with a group of several distinctly different primitive reactive tendencies. As a psychopathologist, the writer finds much interest in the fact that a clinical phenomenon common to the dementia praecox group of psychoses is met with at certain points in the normal ontogenetic and phylogenetic scales; wherever a tendency to " perseveration" exists, it is apt to find expression in the continuous persistence of both useless activities and useless avoidances of activities. The katatonic who continues a motor impulse to the point of catalepsy, or who utters a single word for hours without interruption, is always a patient in whose behavior we expect also to find inordinate persistence of inhibitions. My investigation of normal behavior has disclosed the same association of the one phenomenon with the other in the case of dogs, cats, a horse, and a human infant. The fifth trial of the infant affords an example of this; he tried the various doors in the following order: 3-1-3-4-1-4-3-4-4-4-3-1-4-3-2. Even more striking is the fifty-ninth reaction of Cat 5, who tried the doors in the following order: 3-4-1-3-3-1-3-4-4-1-3-1-3-4-4-1-4-3-2. In each case there are apparent both types of perseveration.

VI. SUMMARY AND CONCLUSIONS

The above interpretations of Types A, B, C, D and E reactions in terms of reactive tendencies to which they may be ascribed now enable us tentatively to assign psychological values to the genetic curves of distribution in figure 3.

(1) *The rational inference tendency* (Type A) is clearly apparent in the behavior of only the eight normal human subjects whose ages range from eight to thirty-four years, and in the behavior of defective Boy A. Morgan's (10) law of parsimony as applied to interpretations of behavior, requires us to assign the behavior of all other subjects, including that of defective Man A, to lower reactive tendencies. We have not ruled out the possibility, of course, that with sufficient experience any of the subjects would manifest a sufficient percentage of Type A reactions to indicate the presence of the rational inference tendency; nor that the subjects who manifested relatively low percentages of these reactions were wholly uninfluenced by the tendency in the question.

(2) *The unmodified searching tendency* (Type B) finds its most frequent expression in the behavior of defective Man A. Among adult animals, the monkeys rank first in this respect, the dogs second, the cats third, and the horse fourth. Of all the subjects, taken as individuals and without regard to age, the horse seems to have been least affected by the unmodified searching tendency.

The ontogenetic findings parallel the phylogenetic; among human subjects, monkeys, dogs of three different age-groups, and cats, there is apparent a tendency for a sufficient decrease in age to decrease the percentage of Type B reactions

(3) *The tendency to adopt stereotyped modes of searching* (Type C) seems to acquire its maximum phylogenetic value for the monkeys; it is but slightly apparent in the behavior of the older normal human subjects and the other mature animals.

The ontogenetic relationships of this reactive tendency are interesting. The immature monkeys and defective Boy A are especially affected by it; but it is more apparent in the behavior of the older puppies than in that of either the mature dogs or the younger puppies. The latter circumstance is a matter of some perplexity to the writer, since, as has been said, the Type C reaction becomes an habitual mode of adjustment with mature dogs who have had sufficiently prolonged experience with the situations of the experiment.

(4) *The searching tendency modified by recrudescent motor impulses* (Type D reaction) regularly increases in frequency of manifestation as we descend the phyletic scale of mature subjects until we reach the mature dogs, at which point it attains its maximum frequency. This tendency decreases as we pass further down the scale through the cats to the horse.

Ontogenetically, it increases in frequency of manifestation with descent from older childhood to infancy; but, with one exception, the younger animals are less affected by it than are their older fellows; the younger puppies give a higher percentage of the Type D reactions than do the older puppies.

(5) *The tendency toward perseveration of active motor impulses and of inhibitions* (Type E) increases regularly in the frequency of its manifestation as both the ontogenetic and phylogenetic scales are descended. It is of interest that during the total one thousand trials of the ten older human subjects (the two defectives being included) there was but one manifestation of this tendency—the first reaction of the much embarrassed Boy 7, whilst 34.21 per cent of the infant's classified reactions may be ascribed to this tendency.

The present investigation has afforded experimental evidence that the phylogenetic and ontogenetic differences of adequacy of mammalian adjustments are to be accounted for not merely in terms of sense-physiology and of associative habit formation, but in terms of reactive tendencies as well. Evidence has also been adduced to support the view that the elaboration of experience involves an interplay of conflicting reactive tendencies, and that these are experimentally isolable according to criteria legitimate to genetic psychology.

A final and still more general conclusion to be drawn from the above is as follows: Since the ideal development of genetic psychology demands the unravelling of long and intricately interwoven mental complexes, not only as they appear in a given species or at a given age, but throughout extensive phyletic and age series, our intensive studies of behavior are apt to become irrelevant to the broader issues in which they seek justification if we do not explore, from time to time, for the general patterns according to which the threads of fact are arranged. The satisfaction derived from the accurate and conclusive determination of the quality and dimensions of a single thread as it appears in a carefully delimited part of its course is apt to blind the genetic psychologist to the historical significance of his own attitude. Darwin (11), Spencer (12), Romanes (13), and Baldwin (14), among others, have sought to deduce from extensive ranges of facts the more general principles of mental development. Their statements concerning general principles have led to the formulation of many detailed problems, and to methods appropriate to the investigation of these problems, with the result that the observations of behavior recorded by the older writers are now shown to have been made under insufficiently controlled conditions, and that their interpretations were often at fault. The obvious need of detailed investigation as thus disclosed, everywhere finds recognition in the work of the younger students of behavior. But the equally obvious need of seeking direction anew from a general survey of comprehensive collections of facts at the expense, if need be, of some sacrifice of accuracy of detail, seems to have gained nothing more substantial than verbal recognition.

The writer begs to acknowledge his indebtedness to Professor Robert M. Yerkes, Professor Adolf Meyer, and Mr. George R. Agassiz for many helpful suggestions and criticisms.

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A NOTE ON LEARNING IN PARAMECIUM

BY LUCY M. DAY AND MADISON BENTLEY

From the Cornell Laboratory for Comparative Psychology

ONE FIGURE

If paramecium learns we may expect to find its learning based upon some slight modification of that "action system" which is brought into function by the common activities of the organism. Modification, however, is not in itself the equivalent of learning. It suggests learning only when it is preserved by the animal and used as an "acquirement" upon a later occasion.

The experiments which follow sought to induce such a modification and to record—should the change persist—its subsequent effects. The protozoa were isolated and studied individually; for it seemed important to duplicate, so far as was possible, the experimental control exercised in the study of the higher forms of life.

With this end in view, the writers made use of the capillary-pool, drawing a single paramecium into a glass tube the diameter of whose lumen was a little less than the animal's length. Then by applying the lips to the larger end of the tube, the pool of culture-water containing the subject was drawn up and away from the tip of the tube and reduced to .5–2.0 cm. in length. The tube was then stuck with bits of wax to a long strip of glass for support and placed at once under the microscope at low power. The observer watched the pool continuously, recording with a key and kymograph backward and forward movements, wheeling movements at the meniscus, partial turns across the tube, and complete changes of direction (reversal). Paramecium succeeded in changing direction by bending its anterior end at the oral groove until the backward beat of the cilia carried it along the wall of the tube and to the rear.[1]

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[1] After the method had been developed, an article on The Limits of Educability in Paramecium, by Stevenson Smith, appeared in the *Journal of Comp. Neur. and Psychol.*, vol. 18, p. 499, 1908. Smith observed reversal in the capillary-tube and remarked that the time was in some cases reduced in the course of 12 hours or more "from 4 or 5 minutes to a second or two" (p. 507). He seems not to have observed the process of reduction or to have controlled chemical changes in the tube. It is worthy of remark that the present writers detected an occasional turn towards the *oral* side. This unusual performance may have been due to contact with the tube; they are at present unable to say.

Table I records the first fifteen reversals for eight individuals. Thus D turned in the tube twenty-five times before it brought its axis around more than 90° and swam to the opposite end of the pool. The next reversal came at the twenty-ninth turn, and so on. The figures at the bottom of the table show that the first two reversals required, on the average, the greatest number of abortive, partial turns (22.6 and 15.5). After that, the averages fall into three groups: 3-4, 5-8, 9-15. The mean variation (last horizontal line) follows the same course. The averages and mean variation for the four groups are: 19.0 ± 3.6, 8.1 ± 1.5, 5.5 ± .3, 3.5 ± .5.

TABLE I

Number of Trials Necessary to Reversal for the First Fifteen Reversals

Reversals / Paramecia	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
D..........	25	29	8	4	3	1	10	3	1	1	2	1	2	1	1
E..........	39	17	2	2	5	3	2	7	2	2	1	1	1	3	1
G..........	13	44	10	37	5	19	5	2	6	1	3	5	8	2	3
H..........	26	17	3	13	16	10	5	20	1	11	12	12	11	12	6
K..........	19	3	1	7	4	6	21	5	2	3	4	4	10	1	5
N..........	20	6	2	3	1	2	1	3	3	2	1	3	1	2	1
O..........	31	5	9	4	3	1	2	1	3	2	2	2	1	4	1
X..........	8	3	18	7	2	2	2	3	8	1	2	4	5	2	5
Average.....	22.6	15.5	6.6	9.6	4.9	5.5	6.0	5.5	3.3	2.9	3.4	4.0	4.9	3.4	2.9
M. V.	7.6	11.3	4.6	7.7	2.9	4.6	4.8	4.0	1.9	2.1	2.3	2.3	3.6	2.3	1.9

Table II gives the total times, in seconds, consumed between successive reversals. As an expression of change in behavior, it is less satisfactory than Table I, because the subjects sometimes became inactive between "trials;" that is, they "wasted time," and since activity tended to diminish with the lapse of time, the periods of quiescence in the latter part of the table mask the actual increase of facility in reversing. A comparison of the two tables, line by line, will make this fact evident. The times do show, however, in spite of this circumstance, a marked decrease. Again, the averages fall roughly into groups: 1-2, 3-7, 8-15. The group-averages stand: 84. ±4.7, 45.8 ±9.3, 33.7 ±4.4. The irregularity in the mean variation is plainly due to wide individual differences of activity.

TABLE II

Time in Seconds Between Reversals

Reversals / Paramecia	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
D..........	117	133	33	24	21	4	36	28	9	2	20	2	12	6	4
E..........	139	78	5	17	9	13	3	39	8	22	2	3	2	11	4
G..........	77	202	95	182	56	137	75	28	49	35	51	64	98	42	49
H..........	65	56	21	65	62	42	45	105	18	134	65	78	65	87	50
K..........	99	32	7	80	37	66	204	50	42	51	66	52	97	2	31
N..........	60	41	41	46	36	39	23	30	41	27	17	46	35	32	19
O..........	102	26	82	12	8	6	8	6	22	7	7	9	5	15	6
X..........	50	16	61	83	16	16	17	16	82	16	16	32	21	15	49
Average.....	88.6	79.3	43.1	63.6	30.6	40.4	51.4	37.8	33.9	36.8	30.5	35.8	41.9	26.3	26.5
M. V........	25.6	50.4	27.1	39.0	17.1	31.0	44.1	20.2	19.6	27.9	22.6	24.3	33.6	20.6	18.3

Thus, G, H, N, and X were either consistently or spasmodically sluggish. The slow and uncertain changes in their behavior may be the direct result of their state, or they may be due to the long blank intervals of "unlearning" between successive reversals. Comparison with D, E, and O (long initial times) suggests the former interpretation.[1]

It was, now, evident to the observers that the apparent increase of facility in turning might be due to some change in the medium (such as increase in CO_2 or decrease in oxygen) brought about by the paramecia themselves. Until this possibility had been eliminated by experimental control, it was impossible to ascribe the changes observed to conscious, or even to purely organic, conditions. A number of subjects were transferred, therefore, at the end of the test, to an open watch-glass of culture-water; then after an interval of ten to twenty minutes they were replaced in the capillary-tube and observed as before. In this way the animal was brought for a second trial under the same external conditions as at first. If the first reduction of times and turns was owing to the environmental changes which we have just assumed to exist, then we might expect the second performance to repeat the first. On the other hand, if the individual had really "learned" during the first trial, we might well look for subsequent modification. The curves, figure 1, give the results (number of partial turns before each successive reversal) for six new subjects, A, B, C, M, Q, and R. In the case of C, we succeeded in carrying the individual through a third test after a second interval of thirty minutes.

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[1] The tests were in all cases carried beyond the fifteenth full turn. The highest number of turns in this set was 123 (subject E). After the fifteenth, however, the subjects either continued to turn with little or no delay or else became inactive. For a further slight increase in facility, see Tables III and IV below.

Tables III, IV, and V are designed to interpret the curves of figure 1. They give the number of reversals in each phase of the curve, together with the average number of partial turns or "trials" necessary to a single reversal.

TABLE III

Paramecia	Phase 1		Phase 2		Phase 3	
	No of reversals.	Ave. No. of trials.	No. of reversals.	Ave. No. of trials.	No. of reversals.	Ave. No. of trials.
A........	10	13.6	40	3.0	23	2.0
B........	10	19.7	60	1.7	19	1.1
C........	5	13.6	75	1.5	46	1.2
M........	5	10.2	30	2.7	38	2.5
Q........	10	4.2	50	1.3	23	1.5
R........	2	13.5	18	2.7	83	1.6
Gen. Ave.	......	12.5	......	2.2	......	1.7
M. V.....	......	3.5	......	.7	......	.4

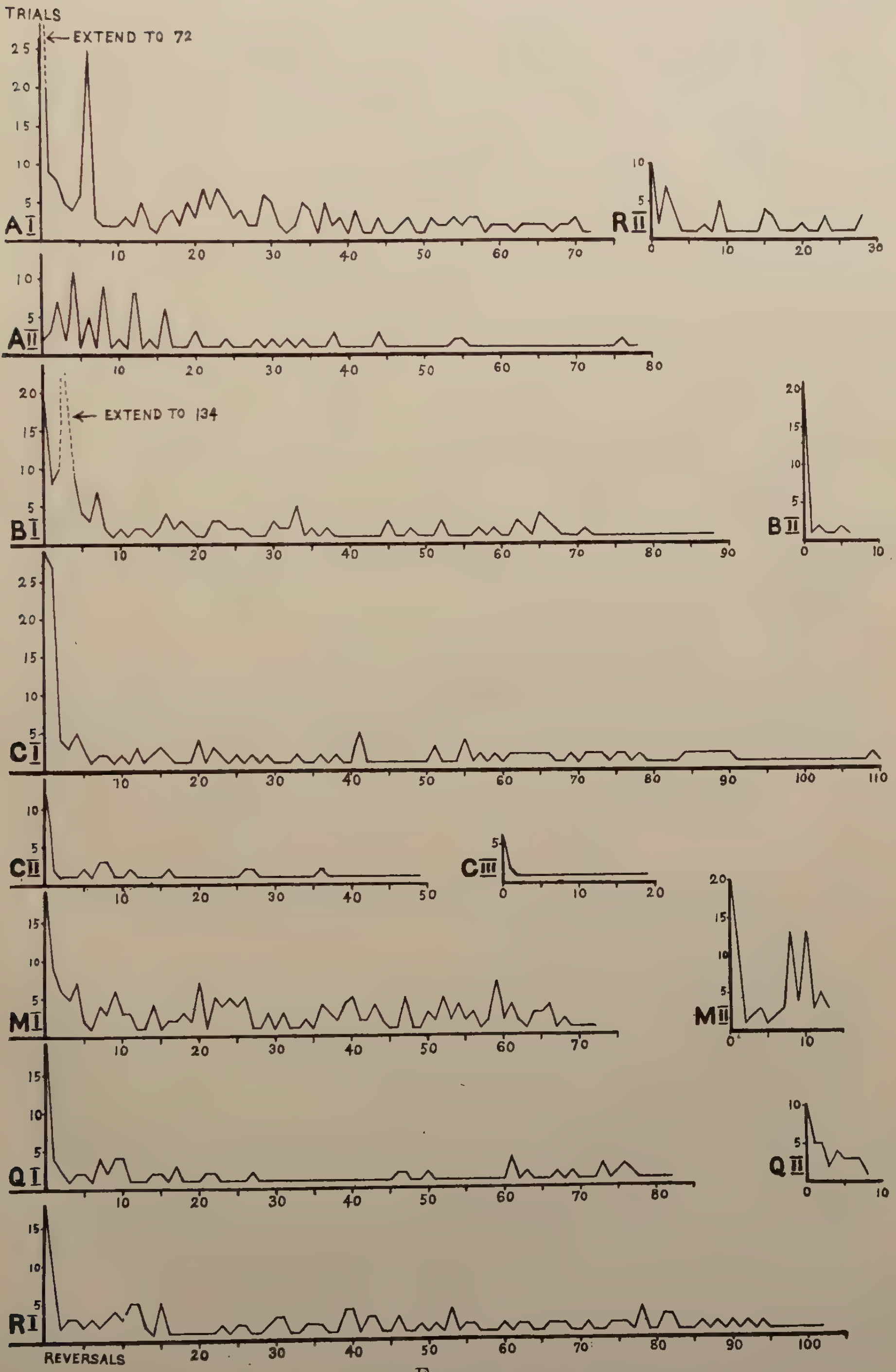
TRIALS
EXTEND TO 72
AI
RII
AII
EXTEND TO 134
BI
BII
CI
CII
CIII
MI
MII
QI
QII
RI
REVERSALS
25
20
15
10
5
0
10
20
30
40
50
60
70
80
90
100
110

Fig. 1.

TABLE IV
AFTER INTERVAL IN WATCH GLASS

Paramecia	Interval (in mins.)	Phase 1		Phase 2	
		No. of reversals	Ave. No. of trials	No. of reversals	Ave. No. of trials
A	10	20	3.4	59	1.2
B	15	1	21.0	6	1.3
C	20	10	2.7	40	1.1
M	10	2	15.5	5	1.8
Q	10	9	4.0	......	......
R	10	5	5.0	24	1.6
Gen. Ave	......	......	8.6	......	1.4
M. V.	......	......	6.4	......	.2

TABLE V
PARAMECIUM C. AFTER SECOND INTERVAL (30 MIN.) IN WATCH GLASS

Phase 1		Phase 2	
No. of reversals	Ave. No. of trials	No. of reversals	Ave. No. of trials
1	6.0	19	1.05

The curves and tables suggest a marked difference in the history of the first and of subsequent tests. The curves for the first test are much like the "trial-and-error" curves for mammalian forms. They begin high, drop quickly if irregularly, pass through a middle, saw-tooth phase, then drop to a low level with small fluctuation (cf. Table I). In the second test, the curve usually starts lower, drops, shows a reduction or absence of the second phase, and ends in a low flat line nearly parallel to the axis of abscissas.[2]

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[2] M and Q are less satisfactory than the others. In the second test, these individuals became very inactive and soon ceased to move. C is perhaps typical; for it maintained active movements nearly the whole time.

A word should be added on the negative cases. We have examined many individuals not reported in the text. Not infrequently the work of whole days came to no issue. But failure was due either to poor cultures, to the technical difficulties of the experiment, or to the sluggish inactivity of the subject. A normal paramecium once brought without injury into a pool of convenient size never failed—provided it remained active after the first few reversals—to show a modification of the type exemplified in the results.

It appears from the experiments (1) that paramecium is capable of modifying within a few minutes its usual avoiding reaction; the lateral turn is so increased and prolonged as to permit the animal to reverse its long axis in a narrow circular tube; (2) that the effect of this modification remains for some time independently of external changes induced. Observations of this nature are taken as evidence of learning. The evidence in this case is supported by the fact that during the process of turning, the animal had the appearance of doing a definite thing. Nevertheless, it is questionable whether this kind of "learning" involves consciousness; whether it is not as well interpreted as the result of purely organic processes.

Further experiments designed to control more closely the conditions of the performance, and especially to ascertain the term of the modification induced, are in progress.

WHEELER ON ANTS [1]

By Robert M. Yerkes

A series of pleasant pictures comes to mind as I write these words. I see myself, in attentive attitude, standing in the midst of a banana plantation in Colombia. On the ground at my feet I see a train, and isolated groups, of animated leaves moving across my pathway. My first thought is, what a beautiful instance of the mimicry of leaves by some insect. A moment later I detect beneath its green burden the huge head and heavy mandibles of a leaf-cutting ant. I had not expected this interesting sight and in consequence I was slow to appreciate its meaning. Yet another picture vividly presents itself. Gathered beside a drainage ditch at the edge of a road-side jungle is a group of native laborers from the plantation. Each is intently watching the ground between the ditch and the jungle. All are talking animatedly. Soon the group dissolves and I see myself standing where it had been. On the ground busily engaged in carrying bits of leaves from place to place, is an army of ants. They are apparently undisturbed by being observed. Each seems intent on reaching his goal. There is a seriousness about the business which is impressive. I wonder what the natives were thinking and saying, what in the appearance and behavior of the insects caused them to attend.

For me these vivid pictures typify the human interest in living things, and they constantly remind me that one need not be a student of the behavior, or structure, or mind of animals in order to be interested in ants. In his book Professor Wheeler treats alike skillfully and in an eminently interesting manner of the structure, the development, the behavior, and the psychology of ants. The work is thorough, although extensive; it is readable even for the amateur naturalist, although scholarly and indicative of careful analytic study of fundamental problems of biology as they are presented in ants. The author is so evidently master of his subject and so deeply interested in making an excellent presentation of the facts that he should be permitted to speak for himself in this review. The book cannot be summarized; one can merely describe it briefly, characterize it in the light of his appreciations, and urge every student of animals to read it.

' It is a matter of common observation that the higher animals—those, namely, that in structure and behavior are most like ourselves—are also the ones which arouse our keenest interest . . . . The only lower animals that from immemorial time have retained a like interest for man are certain insects—the social bees and wasps, the termites and the ants. And among these what appeals so forcibly to the imagination is not the structure or activities of the individuals as such, but the extraordinary instincts which compel them to live permanently in intimate associations (p. 1). No other group of animals presents such a maze of fascinating problems to the biologist, psychologist and sociologist. It will suffice to mention the unrivalled material which they present for the study of variation and geographical distribution, both from the taxonomic and experimental standpoints, the extraordinary phenomena of polymorphism, parthenogenesis and sex determination; the wonderful cases of parasitism and symbiosis, and last, but not least, the great importance of these insects in the problems of instinct and intelligence." (pp. 11, 12)

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[1] Wheeler, William Morton: Ants: their structure, development, and behavior.—The Columbia University Biological Series, IX. New York: The Macmillan Company, 1910. Pp. XXV+663. With 286 text figures and extensive bibliography.

These sentences are quoted from chapter I, which carries the title " Ants as dominant insects," and serves as an admirable introduction to the more technical materials which follow it. The chapter is throughout quotable and exceptionally interesting to students of animal behavior and psychology.

There follow chapters on the external and internal structure and the development of the insects. The descriptions are necessarily brief, but the materials are well chosen and clearly presented. Especially valuable to the naturalist, whether his interests be physiological, psychological, or sociological, is chapter IV, in which a general account of the nervous system is given.

Of the curious chordotonal organs the author writes," Recent studies have shown that these structures, which are present in a great many insects, even in the larval stages, are typically compact, spindle-shaped bundles of sensillae, each consisting of a chitin-secreting gland and a nerve cell. These cells are arranged in a series at an angle to the integument and are stretched, like a tendon, across a cavity between opposite points in the cuticle, or between a point in the cuticle and some internal organ. The gland cell secretes and retains within its cytoplasm a peculiar cone or rod, known as the scolopal body. The chordotonal organs are supposed to be auditory in function, because they are most elaborately developed in the stridulating Orthoptera (crickets and katydids), and because their structure would seem to be adapted to responding like the chords of a musical instrument to delicate vibrations. In ants the development of these sense-organs is greatly inferior to that of the Orthoptera just mentioned but they are nevertheless very easily seen when one knows exactly where to look for them." (pp. 62, 63)

In addition to the chordotonal organs, at least six other types of sense-organ are described; the tactile sensillae (organs of touch); the olfactory and gustatory sensillae (organs of smell and taste); the Johnstonian organ (probably an organ of hearing); the campaniform sensillae (whose function is unknown) the lateral eyes and the median eyes or stemmata (organs of vision).

In a later chapter, XXVII, the functions of the organs of sense are further discussed under the heading," The sensations of ants." At the beginning of this chapter Professor Wheeler makes evident his attitude toward diverse methods of studying animals. He writes, " In endeavoring to gain an insight into the behavior of any animal, two courses are open to us. These may be designated as the intellectual and the intuitional, and it depends on the temperament and training of the observer which he will follow, or whether he will be inclined to follow both. The intellectual course is the one usually pursued by the scientist pure and simple, and is especially exalted by those most thoroughly embued with the spirit of our laboratories, where living organisms are best loved when they are dead, or, at any rate, when they can be subjected to the methods of investigation that have yielded such valuable results to the development of physics and chemistry. . . . . The intuitionist, in dealing with the behavior of animals, proceeds along the path of aesthetic insight, sympathy and introspective knowledge of our own internal processes. His method is, therefore, essentially psychological and metaphysical. He does not deal with things or quantities, but with the living creative movement as immediately experienced in his own consciousness. He attempts to place himself *en rapport* with the organism and to move in the stream of its vital current . . . .

Both methods, when carried to extremes, lead to false or inane, or, at best, very partial interpretations—the scientific to a kind of animal phoronomy, like the reflex-theories of Bethe and Uexküll, the intuitional to the humanizing of animals and all the perversities of the American "nature fakers." . . . . . If I decline to join the ranks of those whose only ambition is to describe and measure the visible movements of animals, and am willing to resort to a comparative psychology in which inferences from analogy with our own mental processes shall have a place, I do this, not because I believe that the former course would be altogether unfruitful or uninteresting, but because the latter seems to me to promise a deeper and more satisfactory insight into the animal mind." (pp. 505, 506, 507.)

Polymorphism receives thorough and illuminating discussion, as do also such topics as the history of myrmecology, the classification and distribution of ants, and fossil ants. A fascinating chapter, XI, on the habits of ants in general prepares the way for detailed accounts of the habits and instincts of the pomerine ants, the driver and legionary ants, the harvesting ants, the fungus-growing ants, and the honey ants. I quote a fragment from chapter XI to indicate the nature of the treatment of habit.

" Having previously described the nuptial flight the author continues his account of the behavior of the female thus. " On descending to the earth the fertilized female divests herself of her easily detached wings, either by pulling them off with her legs and jaws or by rubbing them off against the grass-blades, pebbles or soil. This act of deälation is the signal for important physiological and psychological changes. She is now an isolated being, henceforth restricted to a purely terrestrial existence, and has gone back to the ancestral level of the solitary female Hymenopteron. During her life in the parental nest she stored her body with food in the form of masses of fat and bulky wing-muscles With this physiological endowment and with an elaborate inherited disposition, ordinarily called instinct, she sets out alone to create a colony out of her substance. She begins by excavating a small burrow, either in the open soil, under some stone, or in rotten wood. She enlarges the blind end of the burrow to form a small chamber and then completely closes the opening to the outside world. The labor of excavating often wears away all her mandibular teeth, rubs the hairs from her body and mars her burnished or sculptured armor, thus producing a number of mutilations, which, though occurring generation after generation in species that nest in hard, stony soil, are, of course, never inherited. . . . . . "(pp. 184, 185.) The chapter consists of just such clearly drawn and interesting pictures of ant life as this.

Of the special habits, and other activities and relations, which receive consideration, mention may be made of nest-building, compound nests, the relations of ants to plants, to other insects, and to one another. The chapters on parasitism and slave-making are especially valuable, for they make available in readable form a mass of information which is of extreme importance for a true appreciation of the social life of ants.

Last, and for the student of the mind of animals most important, the chapters on instinct and intelligence may be characterized. They are full of facts, rich in penetrating analyses, stimulating and encouraging to those who despair of the solution of the problems which center about these concepts. Again the author may be permitted to speak for himself.

" If ants exhibited merely the reflexes, or such brief and simple responses to sensory stimuli as we have been considering in the preceding chapter, their lives would flow on with the same monotonous regularity as those of many other insects and the lower invertebrates in general. In addition to these reflexes, however, ants manifest more complicated trains of behavior, the so-called instincts; and both these and the reflexes may be affected with a certain modifiability or plasticity which, in its highest manifestations, has been called intelligence." (p. 518.)

" In addition to instinct, two types of plastic behavior may be distinguished in ants: first, random behavior, like that observed by Jennings, Holmes, Yerkes and others in so many of the lower invertebrates and by Lloyd Morgan, Thorndike, Hobhouse and others in the higher animals. Random, or " trial and error " movements, occur, so to speak, in the very bosom of the instincts, as, for example, when an ant goes out to forage for food that has not as yet been located."

"A second type of behavior is that in which the organism when confronted with a new situation does not proceed to make random movements, but at once adapts itself to the situation by a process which some authors (Loeb, Turner) have called associative memory. The nature of this process is, of course, a matter of conjecture and on this account it is differently conceived by different authors. Before considering this matter, however, we may pass in review the main facts that compel us to postulate the existence of some form of memory in ants. These facts may be grouped under the heads of foraging and homing, recognition of nest mates and aliens, communication, imitation, co-operation and docility " (pp. 531, 532).

" In conclusion it may be noted that all the activities of ants, their reflexes and instincts, as well as their plastic behavior, gain in precision with repetition. In other words, all their activities may be secondarily mechanized to form habits, in the restricted sense of the word. This is tantamount to saying that even the reflexes and instincts are not so steorotyped but that they may become more so by exercise during the lifetime of the individual. And not only do ants thus form habits, but, as several myrmecologists have observed, these habits when once formed are often hard to break. It is certain that many instincts among the higher animals are at first incomplete or indefinite and are guided into their proper course by stimuli that effect the organism at a later period. This is probably true also of many formicine instincts. There is little doubt, more over, that the more fixed or sterotyped instincts are phylogenetically the older. This fact, and the close superficial resemblance of habits to instincts, has led many authors to derive the latter from the former. The views on the origin of automatic behavior, however, are so diverse and conflicting that they cannot be satisfactorily considered without entering into a discussion of the doctrines of the Neodarwinians, Neolamarkians and those who believe in coincident, or organic selection. In my opinion we have little to gain at the present time from such a discussion. . . . . . It is, in fact, quite futile, to attempt a phylogenetic derivation of the automatic from the plastic activities or *vice versa*, for both represent primitive and fundamental tendencies of living protoplasm and hence of all organisms. As instinct, one of these tendencies reaches its most complex manifestation in the Formicidae, while the other blossoms in the intelligent activities of men " (pp. 543, 544).

Professor Wheeler's book commands the attention alike of morphologists, physiologists, and psychologists, and for each group it has much of fact, interpretation, and theory that is of value. Its appearance has helped greatly to establish the scientific status of work in animal behavior and comparative psychology in America. Scientists who are also scholars and men of breadth and sanity of view are too rare for the work of one of them to escape the world's appreciations. " Ants" stands as a comprehensive, reliable, eminently readable, thoroughly scientific account of one of the most important and interesting of organisms.

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